THE UNIVERSITY OF

THE WEST INDIES

ST AUGUSTINE, TRINIDAD AND TOBAGO, WEST INDIES

FACULTY OF MEDICAL SCIENCES

DEPARTMENT OF CLINICAL SURGICAL SCIENCES

OPTOMETRY UNIT

TITLE OF STUDY:

VARIATION OF THE CORNEAL BIOMECHANICAL PROPERTIES OF PATIENTS WITH DRY EYES, KERATOCONIC AND HEALTHY EYES, USING THE OCULAR RESPONSE ANALYZER MACHINE

PRIMARY INVESTIGATOR:

DR. KINGSLEY EKEMIRI (OD, MPH)

STUDENT INVESTIGATORS:

RUQAYYA JUMAN (816025481)

SAARAH HOSEIN (816026421)

ABDULLAH PATEL

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Title of Study: Variation of the corneal biomechanical properties of patients with dry eyes, Keratoconic and healthy eyes, using the Ocular Response Analyzer machine.

Abstract:

Objective: This study intends to investigate the corneal biomechanical properties of persons with dry eye, keratoconus and normal eyes.

Method: This study was a case-control study of the corneal biomechanical properties of patients with dry eye, keratoconus and normal eyes from The UWI Optometry Clinic. A total of 85 subjects and 3 study groups with 35 subjects making up the Healthy eyes control group, 30 subjects making up the Dry eyes group and 20 subjects making up the Keratoconus group.

Results: The CH for dry eyes and normal eyes were determined to be 11.2 mmHg and 11.13 mmHg respectively. The CRF for dry eyes and normal eyes were determined to be 11.14 mmHg and 10.98 mmHg respectively. The CH and CRF for patients with keratoconus were determined to be 8.89 mmHg and 8.32 mmHg respectively.

Conclusion: The findings indicate that there is a significant difference in the corneal biomechanical properties between keratoconic eyes and the healthy eyes group. However, there was no significant difference observed in the dry eyes group compared to the healthy eyes group. Consequently, it was concluded that the Ocular Response Analyzer machine can be employed as a diagnostic tool for keratoconus, but it would not be effective for diagnosing dry eyes.

Introduction:

The cornea plays a vital role in the structure of the eye. The cornea's functions include contributing to two-thirds of the refractive power, as well as maintaining the structural integrity of the eye. With respect to the refractive power, it helps by allowing light rays to bend while entering the eye and focusing onto the retina so that the visual signals can be sent to the brain to form an image.[1] The structural integrity is due to one of the layers forming the cornea, which is the stroma, mostly consisting of water and collagen which gives the cornea its strength, flexibility and structural integrity, and allows it to act as a structural barrier protecting the structures inside the eye from infections or injury.[2]

Corneal biomechanical properties refer to the physical characteristics of the cornea that enable it to withstand external forces and maintain its shape and stability. Two main corneal biomechanical properties are corneal hysteresis (CH) and corneal resistance factor (CRF). Corneal hysteresis is the cornea's ability to deform and return to its original shape when a force is applied and then removed, whereas corneal resistance factor is a measure of the cornea's ability to resist deformation.[3] Abnormalities in corneal biomechanical properties can result in changes to the refractive power leading to decreased visual acuity, and other ocular conditions such as Keratoconus. Therefore, if corneal biomechanical properties are measured and monitored, eye care professionals can have a better chance at assessing the overall health of the eyes and make more informed decisions on diagnosis and treatment options for the patient.[4]

There are several ocular conditions which affect the corneal biomechanical properties. Some of these are Keratoconus, which is a corneal degenerative disease in which the cornea thins, bulges outward, leading to a cone-like deformation which causes changes in the corneal

biomechanical properties, Fuchs' Endothelial Dystrophy which is a progressive disease affecting the cornea's endothelial cells, causing it to deteriorate and lead to corneal Edema and changes in the biomechanical properties, and Dry Eyes which affects the accuracy of the corneal biomechanics measurements when the tear film is unstable or inconsistent.[5] There is also Glaucoma which has been seen in studies that Glaucoma patients have a lower corneal hysteresis than normal, healthy patients.[6]

Some traditional methods of measuring corneal biomechanics include Applanation Tonometry, which utilizes a small probe flattening the cornea to measure the stiffness and resistance of the cornea to deformation, the Ocular Response Analyzer, which is a non-contact tonometer that analyzes the cornea's deformation and rebound ability giving the corneal hysteresis and corneal resistance factor values, Dynamic Scheimpflug Analysis (Corvis ST), which is another non-contact tonometer that takes measurements of corneal deformation and its parameters, and Ultrasonic Elasticity Imaging, which uses ultrasonic waves to assess the elasticity and stiffness of the cornea.[7] Each of these methods may have its limitations such as the ORA is shown to be less repeatable and relatively more expensive than Applanation Tonometry, and the Corvis ST is also relatively expensive and needs trained persons to operate it.[8]

Literature Review:

An accurate assessment of the corneal biomechanical properties is essential for understanding the health of the cornea. [9] The Ocular Response Analyzer is able to perform in vivo biomechanical parameters, that is, the corneal hysteresis and the corneal resistance factor which is an indicator of over corneal elastic characteristics.[9]

According to a survey published by BMC Ophthalmology, out of the 452 participants taking part in the survey, 62.6% were found to have dry eyes and 42% had severely dry eyes. [10] Dry eyes can affect the biomechanical properties as severity increases and is associated with the worsening of corneal biomechanics in patients with low and normal tear productions.[11] According to a clinical study done in England the CH was 10.56 ± 0.025 mmHg in the dry eye group and 10.34 ± 0.26 mmHg in the normal group. Additionally, the CRF was 10.75±0.28 mm Hg in the dry-eye group and 10.70±0.26 mm Hg in the normal group.[12] Hence, the corneal hysteresis and corneal resistance factor did not differ greatly in persons with dry eyes and normal eyes.

As stated by the American Academy of Ophthalmology, keratoconus is characterized by progressive thinning and steepening of the central or paracentral cornea.[13] It is classified according to K values in relation to Stages I - IV; a non-keratoconic person is indicated by a K value more than 7.25mm (< 46.5 D). [14] Studies showed that CH was 10.4 +/- 1.25 in normal eyes and 7.83+/- 1.28 in keratoconic eyes. Additionally, the CRF was 10.23 +/- 1.75 in normal eyes and 9.98 +/- 2.00 in keratoconic eyes.[15] Hence, CH and CRF could be useful in differentiating keratoconic eyes from normal eyes since keratoconic eyes have decreased values in both parameters.

As explained by BMC Ophthalmology, the range of normal corneal biomechanical properties is important since variations are known to indicate early corneal disease as well as glaucomatous damage.[16] Normal corneal biomechanics, that is, corneal hysteresis was averaged to

be 10.23 +/- 1.75 in normal eyes and the corneal response factor was averaged to be 10.23 +/- 1.75 in normal eyes.[15] The same study showed that age is strongly associated with CH and CRF as well as other contributing factors. Furthermore, studies showed that there were no significant differences between the sexes. [17]

A similar study to this one was published in the Egyptian Journal of Hospital Medicine where they compared the corneal biomechanics in normal and keratoconic corneas using the Ocular Response Analyzer.[18] The outcome of this study was they found that the corneal hysteresis values were higher in the normal eyes group than the keratoconic eyes group, and the corneal resistance factor was found to be higher in the keratoconic eyes group than the normal eyes group. As mentioned before, a study found that corneal biomechanical properties were not influenced by dry eye. [12]

There are limitations for the Ocular Response Analyzer with respect to measuring corneal biomechanics due to variations in the hydration of the cornea. Changes to hydration have been confirmed to have an effect on biomechanics in several studies.[19] Additionally, CH values have been demonstrated to be influenced by IOP and central corneal thickness[19], hence, the values can vary based on corneal thickness. Hence, further alterations need to be made to the ORA to improve the accuracy of the measurements.

In summary, corneal biomechanical properties can be used to understand ocular conditions such as dry eye and keratoconus. Furthermore, there is a need for further research to understand the variations in corneal biomechanics in healthy individuals and the limitations of the ORA in relation to taking accurate measurements in order to accurately compare ocular conditions.

Rationale/Problem Statement:

The cornea plays an important role in maintaining the structural integrity and the visual function of the eyes. Changes to corneal biomechanics such as corneal hysteresis and corneal resistance factor can be used as an indicator of ocular health. The Ocular Response Analyzer (ORA) is a non-invasive ophthalmic device which was developed by Reichert Technology in 2005 and will be used in this study to measure biomechanical properties of participants' corneas. It involves the application of a puff of air to the cornea, meanwhile measuring certain biomechanical parameters of the cornea by emitting infrared light and analysis of the shape of the cornea by assessing the subsequent infrared waveform signal produced. The viscoelastic properties of the cornea are measured which include Corneal Hysteresis (CH) and Corneal Resistance Factor (CRF).

Keratoconus is a degenerative corneal disease in which the corneal structure progressively changes, with thinning, outward bulging and an overall cone shaped deformation occurring. These physical and structural changes may result in alterations in biomechanical properties of the cornea such as central corneal thickness reduction. Corneal hysteresis and corneal resistance factor changes may also be expected due to a change in the structural integrity of the cornea.

Dry Eye Disease (DED) involves corneal changes due to the lack of an optimal tear surface presence and the subsequent lack of lubrication and protection of the corneal epithelium, which would subsequently result in a change of the corneal structure. Therefore, there is a potential for alteration to the corneal biomechanics.

These changes in a patient's corneal biomechanics leave them even more susceptible to other corneal complications such as corneal oedema and at a greater risk of symptoms from corneal

abrasions. Additionally, reductions in hysteresis and central thickness of the cornea may result in a patient being more susceptible to conditions such as glaucoma and loss of vision.

The purpose of this study is to investigate the variation of corneal biomechanical properties in patients with dry eyes, keratoconus and healthy eyes using the ORA. This research intends to provide information in different groups of patients, which can be inferred and applied clinically to allow for early diagnosis of ocular conditions such as keratoconus and dry eye disease.

This study is important due to the lack of previous research regarding the variation of corneal biomechanical properties in patients with Dry Eyes Disease (DED), keratoconus, and healthy eyes among multiethnic populations such as Trinidad and Tobago, leaving a research gap in this area, with need for more data for all three groups, especially in the case of DED due to the growing prevalence. This research can aid in the diagnosis and management of ocular conditions and enhance the understanding of corneal biomechanics.

Research Questions:

1. What are the corneal biomechanical properties of patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?
2. Are there significant differences in corneal biomechanical properties between patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?
3. How do corneal biomechanical properties vary with age and gender in patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?
4. How can the results of this study be used to improve the diagnosis and management of ocular conditions such as dry eyes and keratoconus?

Aim of Study:

The aim of the study is to evaluate and compare corneal biomechanical parameters in both eyes of patients with moderate dry eyes and stage one and two Keratoconic eyes among a multiethnic Trinidadian population, in order to help in early detection and management of these diseases. The main objective of this study is to measure and compare the corneal biomechanical properties of individuals with dry eyes, Keratoconus, and healthy eyes using the Ocular Response Analyzer machine.

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Objectives of Study:

1. To measure and compare the corneal biomechanical properties (corneal hysteresis and corneal resistance factor) of patients with dry eyes, keratoconus, and healthy eyes using the ORA machine.
2. To determine if there are significant differences in corneal biomechanical properties between patients with dry eyes, keratoconus, and healthy eyes using the ORA machine.
3. To examine how corneal biomechanical properties vary with age and gender in patients with dry eyes, keratoconus, and healthy eyes using the ORA machine.
4. To explore how the results of this study can be used to improve the diagnosis and management of ocular conditions such as dry eyes and keratoconus, including identifying any correlations between corneal biomechanical properties and clinical outcomes.

Ethical Approval / Considerations:

Ethical approval was granted by The Campus Campus Research Ethics Committee to conduct this research with reference number CREC-SA.1795/10/2022. Permission was also granted by the UWI Optometry Clinic to conduct research on this topic. Research procedures were performed in accordance with the World Medical Association's (WMA) Declaration of Helsinki.

Patient files were accessed through the UWI Optometry Clinic after permission was granted.

Consent forms and questionnaires used in this study involved no recorded names, thus, data collection was coded and anonymous. Hence, statistical information being shared via presentation to discuss the analysis of our data, patient names would not be mentioned.

Methodology:

This section describes the study setting, study design, study population, study sample as well as the procedures involved in data collection, data analysis and data protection, in order to provide a concise understanding of how the study took place.

Study Setting

This study was conducted in the University of the West Indies Optometry Clinic at the Couva Multi-Training Facility in Trinidad, specifically Central Trinidad, to the south of the capital city, Port of Spain. The University of the West Indies Optometry department is a part of the medical sciences faculty of the St. Augustine campus of the University of the West Indies.

Study Design

This research was a case-control study, in which participants were recruited from a single eye clinic. The study included three groups: healthy eyes, dry eyes, and keratoconic eyes. Healthy eyes

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patients were the group used as the control, while dry eyes and keratoconic eyes were the group cases being observed.

The data measurement approach was to obtain quantitative data by recording clinical data pertaining to the patients' eyes by carrying out non-invasive testing of the patients' eyes using the Ocular Response Analyzer machine.[20]

This quantitative data of the patients' eyes was focused on the biomechanical properties of the patients' corneas, as well as confirmation data to ensure participants are from the appropriate case-control group.[20]

Study Population

The research included adults over 18 years of age, of various races in Trinidad and Tobago, with keratoconus, dry eye disease, and healthy eyes. The participants were selected from clinic patients who were either informed and requested to participate in the study face to face within the clinic or by a telephone call. Before any data was collected, the patients were educated about the study, its details, and the participation procedures, followed by a request for written consent.

Study Sample

The sample technique used was non-probability sampling in order to obtain the three different groups of persons wanted for the study. Group 1 consisted of persons with healthy eyes, who were required as the control of the study while the other 2 groups were the case groups required to be

studied in this research. Group 2 consisted of persons with dry eyes and group three consisted of persons with keratoconic eyes.

Sample Size

The study sample size was determined using Epitool software which was developed by an epidemiology consulting company called Ausvet. Purposive sampling approach was the sampling approach used which led to the sample size determined to be 168 persons with 56 patients per group having used a p value of 0.05. The expected proportion exposed in controls is 0.05, the assumed odds ratio is 3, the confidence level is 0.95 and the desired power is 0.85.

Inclusion Criteria

The inclusion criteria used was adult persons aged 18-65 years who lived in Trinidad and Tobago permanently and had either healthy eyes, stage one and two keratoconus or moderately dry eyes.

Exclusion Criteria

The exclusion criteria used were people who have some significant ocular pathology other than keratoconus or dry eye or people who are located outside of Trinidad and Tobago as well as persons under 18 and over 65.

Data collection

Researchers were instructed by the laboratory technician of the UWI Optometry Clinic in the appropriate use of the ORA device as well as the topographer to prepare for the measurement procedures involved with the patients. Additionally, the researchers were trained in how to assess the clinic records to find participants required for the research.

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A questionnaire was designed in order to obtain preliminary information from patients. A consent form was designed to provide patients with a formal and thorough description of the research and the process they will be involved in, as well as to formally obtain their written consent.

Participants of the appropriate testing groups were identified and selected using the patient clinic record files of the UWI Optometry Clinic. These patients were then contacted via telephone to be informed about the study and requested to participate. Additionally, some patients already at the UWI Optometry clinic were approached, informed about the study, and asked to participate.

Participants were instructed to read and consent to a written consent form upon arrival to the clinic. They were then asked to fill out the questionnaire to collect their demographic data and to ensure that they were a part of the intended group to study.

Patients were tested for visual acuity to ensure healthy eyes patients were in the correct group.

Using a Slit Lamp Biomicroscope, the Van Herick grading test was then performed on the patient, with their angle opening measured and recorded to ensure they were not at risk for Glaucoma as part of the exclusion criteria.

Corneal topography readings and tear break up time were measured and recorded, with patients possessing a tear break up time less than 10 seconds being noted as dry eye patients.

The stage of keratoconus was determined using the K readings obtained from the topography readings as well as corresponding visual acuity. Stage 1 was determined as an average K reading between 6.35 mm and 7.05 mm and stage 2 was determined as an average K reading between 6.15 mm and 6.35 mm.[24] The axial maps were also taken into consideration along with their corrected distance visual acuity.

The patient was then accurately grouped using the collected data and subsequently tested with the ORA with values of IOPcc (IOP with corneal correction), IOPg (Goldman correlated IOP), CRF (corneal response factor), CCF (corneal constant factor), CH (corneal hysteresis) and P1(the inward applanation pressure) and P2(the outward applanation pressure). all being measured.

Data Analysis

The data collected was analyzed using SPSS software to compare the data collected from the three different groups and assess each of the objectives of the study.

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Firstly, descriptive statistics such as mean, standard deviation and range were done to gain information about the typical values and variability of the corneal biomechanical properties in each group in order to answer the first research question, "What are the corneal biomechanical properties of patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?"

An analysis of variance, or ANOVA test, which is an inferential statistic test was done to compare the corneal biomechanical properties between the groups and identify if any of the groups differ significantly from the others. This analysis helped in answering the second research question, "Are there any significant differences in corneal biomechanical properties between patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?"

To answer the third research question, "How do corneal biomechanical properties vary with age and gender in patients with dry eyes, keratoconus, and healthy eyes using the ORA machine?", linear regression analysis was done to examine the relationship between age, gender, and the corneal biomechanical properties for each group. This helps to identify if there are any significant associations between age, gender, and corneal biomechanical properties, as well as determine how these properties can vary with age and gender.

Receiver Operating Characteristic (ROC) curve analysis was then done to determine whether the Ocular Response Analyzer machine can be used as a diagnostic tool for the detection and monitoring of corneal biomechanical changes in individuals with dry eyes and keratoconus.

Lastly, the results of the study were interpreted in the context of current diagnostic and treatment strategies for dry eyes and keratoconus, in order to answer the fourth research question "How can the results of the study be used to improve the diagnosis and management of ocular conditions such as dry eyes and keratoconus?". These findings from the study may suggest new ways to diagnose and manage these conditions based on the differences in corneal biomechanical properties observed in this study.

Data Protection

The data was protected by using a code number for names, addresses or phone numbers. Furthermore, patient confidentiality was secured by restricting access to the data by the researcher.

Results:

- Demographic profile

This study consisted of a total of 85 subjects and three study groups with 35 subjects making up the Healthy eyes control group, 30 subjects making up the Dry eyes group and 20 subjects making up the Keratoconus group.

For the Healthy eyes group, their ages ranged from 18 to 65 years with a mean age (± SD) of 31.63 ± 14.68 years. Majority of the subjects were females (n = 22, 62.86%) and the highest participating age group was 18 – 24 year olds (n = 17, 48.57%).

For the Dry eyes group, their ages ranged from 18 to 65 years with a mean age (± SD) of 30.53 ± 14.18 years. Majority of the subjects were females (n = 22, 73.33%) and the highest participating age group was 18 – 24 year olds (n = 18, 60.0%).

For the Keratoconus eyes group, their ages ranged from 18 to 65 years with a mean age (± SD) of 36.20 ± 12.86 years. Majority of the subjects for this group were females (n = 12, 60.00%), and the highest participating age group was 32 – 38 year olds (n = 8, 40.00%).

Variable	Subgroup	Healthy Eyes Group		Dry Eyes Group		Keratoconus Eyes Group	
		Frequency (N = 35)	**Percentage (N = 100%)**	**Frequency (N = 30)**	**Percentage (N = 100%)**	**Frequency (N = 20)**	**Percentage (N = 100%)**
Gender	**Male**	13	37.14%	8	26.67%	8	40.00%
	Female	22	62.86%	22	73.33%	12	60.00%
Age	**18-24**	17	48.57%	18	60.00%	4	20.00%
	25-31	7	20.00%	3	10.00%	2	10.00%
	32-38	2	5.71%	2	6.66%	8	40.00%
	39-45	2	5.71%	2	6.66%	2	10.00%
	46 and above	7	20.00%	5	16.66%	4	**20.00%**

Table 1.0 : Demographic Profile of the three groups studied – Healthy Eyes, Dry Eyes and Keratoconus Eyes

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recalculate the frequency and percentage

- Descriptive statistics of corneal biomechanical properties of patients with dry eyes, keratoconus and healthy eyes:

The findings indicate that the typical value for corneal hysteresis (CH) for dry eyes is 11.2 mmHg. The typical value for CH is for keratoconic eyes is 8.89 mmHg. The typical value for CH for normal eyes is 11.13 mmHg. The standard deviation among the groups is small which means the data is clustered around the mean and there is low variability. The range was also small which indicated that the values were similar and there were few outliers.

The findings also indicate that the typical value for corneal resistance factor (CRF) for dry eyes is 11.14. The typical value for CRF for keratoconic eyes is 8.32. The typical value for CRF for normal eyes is 10.98. The standard deviation among the groups is small which means the data is clustered around the mean and there is low variability. The range was also small, which indicated that the values were similar and there were few outliers.

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	Dry eyes		Keratoconus		Healthy eyes	
	OD/ mmHg	OS/mmHg	OD/mmHg	OS/mmHg	OD/mmHg	OS/mmHg
Mean	11.23	11.17	8.99	8.80	11.01	11.25
Standard deviation	1.69	1.81	1.79	1.80	1.90	1.68
Range	8.00	7.60	5.70	6.60	8.10	7.50

Table 2.0 showing descriptive statistics of corneal hysteresis among the three groups.

	Dry Eyes		Keratoconus		Healthy eyes	
	OD/mmHg	OS/mmHg	OD/mmHg	OS/mmHg	OD/mmHg	OS/mmHg
Mean	11.15	11.12	8.30	8.33	10.96	10.99
Standard deviation	1.84	2.14	2.11	2.44	2.01	1.70
Range	7.9	8.4	7.2	8.3	7.10	7.40

Table 2.1 showing descriptive statistics of corneal resistance factor among three groups.

- Significant differences in corneal biomechanical properties between patients with dry eyes, keratoconus, and healthy eyes.

The p values of CH for the dry eyes group shows that there was no statistically significant difference in corneal biomechanical properties between this group and the healthy eyes group (p-value > 0.05), whereas for the keratoconus eyes group, there was a statistically significant difference in corneal biomechanical properties between this group and the healthy eyes group (p-value < 0.05). According to the keratoconus eyes group t-values, which are positive, the healthy eyes group is statistically significantly different from the keratoconus eyes group.

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	Dry Eyes		Keratoconus Eyes	
	OD	**OS**	**OD**	**OS**
T – value	-0.491	0.171	3.937	4.951
P – value	0.313	0.432	< 0.001	< 0.001

Table 3.0 showing inferential statistics of corneal hysteresis for dry eyes and keratoconus eyes.

	Dry Eyes		Keratoconus Eyes	
	OD	**OS**	**OD**	**OS**
T – value	-0.391	-0.259	4.567	4.302
P – value	0.349	0.398	< 0.001	< 0.001

Table 3.1 showing inferential statistics of corneal resistance factor for dry eyes and keratoconus eyes.

The p values of CRF for the dry eyes group shows that there was no statistically significant difference in corneal biomechanical properties between this group and the healthy eyes group (p-value > 0.05), whereas for the keratoconus eyes group, there was a statistically significant differences in corneal biomechanical properties between this group and the healthy eyes group (p-value < 0.05). According to the keratoconus eyes group t-values, which are positive, the healthy eyes group is statistically significantly different from the keratoconus eyes group.

- The variation of corneal biomechanical properties with age and gender in patients with dry eyes, keratoconus and healthy eyes:

	P value	Correlation coefficient, r	Significance
CH	0.023	0.493	S
CRF	0.081	0.413	NS

Table 4.0 shows regression analyses for dry eye group with a significance level of 0.05.

The regression analysis for dry eye patients shows that there is an association between age and gender with corneal hysteresis (p-value < 0.05). There was no association between CRF and its association with age and gender (p-value >0.05).

	P value	Correlation coefficient, r	Significance
CH	0.138	0.456	NS
CRF	0.003	0.699	S

Table 4.1 showing regression analyses for keratoconus group with a significance level of 0.05.

The regression analysis for keratoconus patients shows that there is no association between age and gender with corneal hysteresis (p-value > 0.05). There was an association between CRF and its association with age and gender (p-value <0.05).

	P value	Correlation coefficient, r	Significance
CH	0.334	0.257	NS
CRF	0.819	0.112	NS

Table 4.2 shows regression analyses for normal eyes group with a significance level of 0.05.

The regression analysis for healthy eyes for both CH and CRF showed no association with gender and age. (p-value > 0.05)

- Can the Ocular Response Analyzer machine be used as a diagnostic tool for detecting and monitoring corneal biomechanical changes in individuals with Dry eyes and Keratoconus eyes.

	Dry Eyes		Keratoconus Eyes	
	OD	**OS**	**OD**	**OS**
P value	0.742	0.911	0.001	0.000

Table 5.0 shows Corneal Hysteresis p values obtained from ROC curve analysis of Dry eyes and Keratoconus eyes.

The ROC curve analysis for CH in the dry eyes group showed that the Ocular Response Analyzer cannot be used as a diagnostic tool (p-value > 0.05), whereas for the keratoconus eyes group it can be used as a diagnostic tool (p-value < 0.05).

	Dry Eyes		Keratoconus Eyes	
	OD	**OS**	**OD**	**OS**
P value	0.072	0.074	0.000	0.000

Table 5.1 shows Corneal Resistance Factor p-values obtained from ROC curve analysis of dry eyes and keratoconus eyes.

The ROC curve analysis for CRF in the dry eyes group showed that the Ocular Response Analyzer cannot be used as a diagnostic tool (p-value > 0.05), whereas for the keratoconus eyes group it can be used as a diagnostic tool (p-value < 0.05).

- Interpretation of the results based on differences in corneal biomechanical properties and how they can be used to diagnose or treat dry eye or keratoconus.

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The CH for dry eyes and normal eyes were 11.2 mmHg and 11.13 mmHg respectively. Inferential statistics showed that there was no statistically significant difference in corneal biomechanical properties between the dry eye group and the healthy eyes group, hence, CH cannot be used to diagnose or manage dry eyes. Additionally, the ROC curve analysis for CH in the dry eyes group showed that the Ocular Response Analyzer cannot be used as a diagnostic tool. However, the regression analysis for dry eye patients shows that there is an association between age and gender with corneal hysteresis.

The CRF for dry eyes and normal eyes were 11.14 and 10.98 mmHg respectively. Inferential statistics showed that there was no statistically significant difference in corneal biomechanical properties between the dry group and the healthy eyes group, hence CRF cannot be used to diagnose or manage dry eyes. Additionally, the ROC curve analysis for CRF in the dry eyes group showed that the Ocular Response Analyzer cannot be used as a diagnostic tool. Regression analysis for dry eye patients shows that there is no association between age and gender with CRF.

The CH for keratoconus eyes and normal eyes were 8.89 mmHg and 11.13 mmHg respectively. Inferential statistics showed that there was a statistically significant difference in corneal biomechanical properties between this group and the healthy eyes group, hence, CH can be used to diagnose and manage keratoconus. Additionally, the ROC curve analysis for CH showed that CH can be used as a diagnostic tool in keratoconus. The regression analysis for keratoconus patients shows that there is no association between age and gender with CH.

The CRF for keratoconus eyes and normal eyes were 8.32 mmHg and 10.98 mmHg respectively. Inferential statistics showed there was a statistically significant differences in corneal biomechanical properties between the keratoconus group and the healthy eyes group, hence, CRF can be used to diagnose and manage keratoconus. Additionally, the ROC curve analysis showed that CH can be used as a diagnostic tool in keratoconus. The regression analysis for keratoconus patients shows that there is an association between age and gender with CRF.

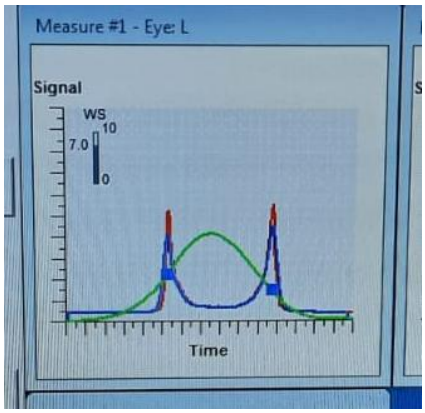

Figure 1.0 showing the graph produced by the ORA for a healthy eye participant

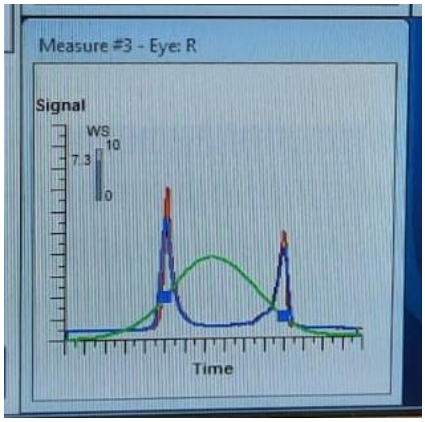

Figure 2.0 showing the graph produced by the ORA for a dry eyes participant

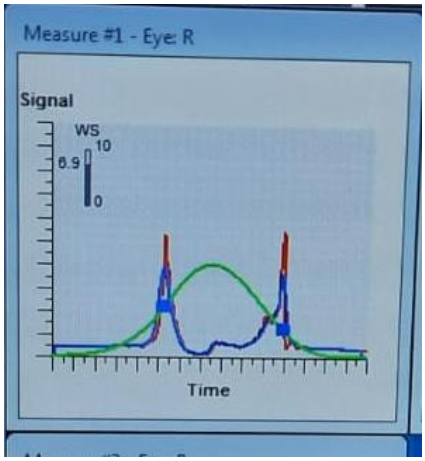

Figure 3.0 showing the graph produced by the ORA for a keratoconus eyes participant

Discussion:

The social demographics of this study includes the age and gender of the participants. This study consisted of both males and females, however the majority of participants were females for all three study groups with the healthy eyes group having 62.86%, the dry eyes group having 73.33%, and the keratoconus eyes group having 60% females. This was a similar finding in a dry eyes study done in Dubai where the majority of participants were also females (63.7%)[10], however in a study done by an Egyptian Journal it was found that more men participated in the healthy eyes group but more women participated in the keratoconic group.[18]

With respect to age, the mean age for the healthy eyes group was 31.63 ± 14.68 years, the dry eyes group was 30.53 ± 14.18 years, and the keratoconus eyes group was 36.20 ± 12.86 years. In a study done by an Egyptian Journal, they found the mean age of their keratoconus eyes group to be 23.70 ± 5.97 years which is significantly lower than our findings, however their healthy eyes group was similar to ours with a mean age of 29.90 ± 3.60 years.[18]

The CH of patients with dry eye was determined to be 11.2 mmHg, while the CH of normal eyes was determined to be 11.13 mmHg. This was a bit higher than a clinical study done in England where the CH was 10.56 ± 0.025 mmHg in the dry eye group and 10.34 ± 0.26 mmHg in the normal group.[12] The CRF of patients with dry eye was determined to be 11.14 mmHg, while the CRF of normal eyes were determined to be 10.98 mmHg. In the same study, the CRF was 10.75±0.28 mm Hg in the dry eye group and 10.70±0.26 mm Hg in the normal group.[12]

The CH of patients with keratoconus was determined to be 8.89 mmHg while the CRF of keratoconus eyes was determined to be 8.32 mmHg. This was similar to studies which showed that CH was 10.4 +/- 1.25 mmHg in normal eyes and 7.83+/- 1.28 mmHg in keratoconic eyes. Additionally, the CRF was 10.23 +/- 1.75 in normal eyes and 9.98 +/- 2.00 in keratoconic eyes.[15]

The findings showed that there were no statistically significant differences between the corneal biomechanical parameters, Corneal Hysteresis and Corneal Resistance Factor, of the healthy eyes group and the dry eyes group. A similar finding was shown in a study done in London where they concluded that there was no statistically significant difference in the CH and CRF measurements between healthy eyes and dry eyes participants.[12]

Conversely however, it was found that there were statistically significant differences between the corneal biomechanical parameters of the healthy eyes group and keratoconus eyes group. This finding is supported by studies that stated that CH and CRF measurements have been shown to be reduced in keratoconic eyes.[23]

The sociodemographic characteristic of this study comprised of both males and females. The findings showed that there was a relation between corneal hysteresis and dry eye with gender and age, however, there was no relation between CRF and the demographic data. Furthermore, there was a relation between CRF with gender and age, however, there was no relation between CH and the demographic data. This coincided with studies that showed that there were no significant differences between the sexes.[17] [18] Any relation to changes in corneal biomechanics with respect to demographic data, may have been correlated to the age of the patient as seen in a study that showed that age is strongly associated with CH and CRF.[15]

The findings showed that the ORA cannot be used as a diagnostic tool in relation to dry eye disease. On the other hand, it can be used to diagnose and manage keratoconus since there was a statistically significant difference between the corneal biomechanics of the keratoconus group and the normal group for both CH and CRF. This was synchronous with a study from the Egyptian Journal of Hospital Medicine in which CH and CRF were concluded as indicators of diagnosis.

Limitations of Methodology:

- The use of lubrication drops for persons with dry eyes were not taken into consideration, therefore, this may have affected findings related to the TBUT, Schirmer's test and the measurement of the corneal biomechanical properties.
- Corneal Collagen Cross Linking was not taken into consideration and how it may have affected the corneal biomechanical properties.
- Age and gender were not fixed within the three groups.

Conclusion:

In this study, the corneal biomechanical properties of healthy eyes, dry eyes and keratoconic eyes were measured using the Ocular Response Analyzer machine. These parameters were evaluated and compared to determine if there are significant differences in the corneal biomechanical properties of persons with dry eyes and keratoconic eyes, and whether the Ocular Response Analyzer machine can be used to diagnose these ocular diseases.

It can be concluded that there is a significant difference in the corneal biomechanical properties of keratoconic eyes compared to the healthy eyes control group, however there was no significant difference in the dry eyes group compared to the control group. Also, it was determined that the Ocular Response Analyzer machine can thus be used as a diagnostic tool for keratoconus, but not for dry eyes.

Recommendations:

1.) There should be more studies done on this topic within the Caribbean as there was insufficient data found on a regional level.
2.) Further studies should also be done investigating the Ocular Response Analyzer as a diagnostic tool for Keratoconus and other ocular diseases.
3.) The study can be replicated with an increased sample size, including Tobago, to see whether the results will remain consistent.

Next steps:

The next steps would include the preparation of this research to influence the diagnostic tools and management associated with keratoconus. Additionally, this data can be used as a foundation for further studies into corneal biomechanical properties and how it relates to both dry eyes and

keratoconus. Hence, optometrists can have a better understanding of how to manage both conditions to promote patient care and satisfaction.

References:

1. Sridhar MS. Anatomy of Cornea and Ocular Surface. Indian Journal of Ophthalmology [Internet]. 2018;66(2):190–4. Available from: https://journals.lww.com/ijo/Fulltext/2018/66020/Anatomy_of_cornea_and_ocular_surface.4.aspx

2. Esporcatte LPG, Salomão MQ, Lopes BT, Vinciguerra P, Vinciguerra R, Roberts C, et al. Biomechanical Diagnostics of the Cornea. Eye and Vision [Internet]. 2020;7(1). Available from: https://eandv.biomedcentral.com/articles/10.1186/s40662-020-0174-x#citeas

3. Kent C. Measuring Ocular Biomechanics [Internet]. Review of Ophthalmology. 2006. Available from: https://www.reviewofophthalmology.com/article/measuring-ocular-biomechanics

4. Moshirfar M, Lin A, Woodward M, Bernfeld E, Reddy V. Corneal Biomechanics [Internet]. American Academy of Ophthalmology EyeWiki. 2022. Available from: https://eyewiki.aao.org/Corneal_Biomechanics#:~:text=An%20understanding%20of%20corneal%20biomechanics,impact%20on%20surrounding%20ocular%20tissues

5. Zhao Y, Hu G, Yan Y, Wang Z, Liu X, Shi H. Biomechanical Analysis of Ocular Diseases and its In Vitro Study Methods. BioMedical Engineering OnLine [Internet]. 2022;21(1). Available from: https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-022-01019-1

6. Dascalescu D, Corbu C, Constantin M, Cristea M, Ionescu C, Cioboata M, et al. Correlations between Corneal Biomechanics and Glaucoma Severity in Patients with Primary

Open Angle Glaucoma. Maedica [Internet]. 2015;10(4):331–5. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5394446/

7. Aziz K, Friedman DS. Tonometers—which one should I use? Eye (London) [Internet]. 2018;32(5):931–7. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5944656/

8. Salouti R, Alishiri A, Gharebaghi R, Naderi M, Jadidi K, Shojaei-Baghini A, et al. Comparison among Ocular Response Analyzer, Corvis ST and Goldmann applanation tonometry in healthy children. International Journal of Ophthalmology [Internet]. 2018 [cited 2020 Mar 23];11(8). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6090110/

9. Li F, Wang K, Liu Z. In vivo biomechanical measurements of the cornea [Internet]. MDPI. Multidisciplinary Digital Publishing Institute; 2023 [cited 2023Apr22]. Available from: https://www.mdpi.com/2306-5354/10/1/120/pdf

10. Alkabbani S, Jeyaseelan L, Rao A, Thakur S, Warhekar P. The prevalence, severity, and risk factors for dry eye disease in Dubai – a cross sectional study [Internet]. BMC Ophthalmology. 2021 [cited 14 September 2022]. Available from: https://bmcophthalmol.biomedcentral.com/articles/10.1186/s12886-021-01978-4#citeas

11. Satitpitakul, V., Taweekitikul, P., Puangsricharern, V., Kasetsuwan, N., Reinprayoon, U. and Kittipibul, T., 2021. Alteration of Corneal Biomechanical Properties in Patients with Dry Eye Disease. [online] PubMed Central. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8274861/

12. Firat PG, Doganay S. Corneal hysteresis in patients with Dry Eye [Internet]. Eye (London, England). U.S. National Library of Medicine; 2011 [cited 2023Apr22]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3234461/

13. Feldman BH. Keratoconus [Internet]. American Academy of Ophthalmology . 2023 [cited 2023Apr22]. Available from: https://eyewiki.aao.org/Keratoconus

14. Belin MW, Kundu G, Shetty N, Gupta K, Mullick R, Thakur P. ABCD: A new classification for Keratoconus [Internet]. Indian journal of ophthalmology. U.S. National Library of Medicine; 2020 [cited 2023Apr22]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7856970/

15. Mohammadpour M, Etesami I, Yavari Z, Naderan M, Abdollahinia F, Jabbarvand M. Ocular response analyzer parameters in healthy, keratoconus suspect and manifest Keratoconus Eyes [Internet]. Oman journal of ophthalmology. U.S. National Library of Medicine; 2015 [cited 2023Apr22]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4640019/

16. Kotecha A, Russell RA, Sinapis A, Pourjavan S, Sinapis D, Garway-Heath DF. Biomechanical parameters of the cornea measured with the ocular response analyzer in Normal eyes - bmc ophthalmology [Internet]. BioMed Central. BioMed Central; 2014 [cited 2023Apr22]. Available from: https://bmcophthalmol.biomedcentral.com/articles/10.1186/1471-2415-14-11

17. Repeatability of Ocular Response Analyzer Metrics: A gender-based study [Internet]. Optometry and vision science : official publication of the American Academy of Optometry. U.S. National Library of Medicine; 2013 [cited 2023Apr22]. Available from: https://pubmed.ncbi.nlm.nih.gov/23770655/

18. Khedr SA, El-Shazly AA, Nada OT, Abouelezz KA. Comparison between corneal biomechanics in normal and keratoconic corneas using ocular response analyzer. The Egyptian Journal of Hospital Medicine. 2017Oct;69(4):2191–8. [cited 2022Nov02] Available from: https://www.google.com/url?sa=t&source=web&rct=j&url=https://ejhm.journals.ekb.eg/article_11853_c332395f2b4b106796c4810339cde649.pdf&ved=2ahUKEwjwgpjR_pL7AhWIn4QIHURCAPM4ChAWegQIAhAB&usg=AOvVaw3zRCkxCaK9nucY1uVGBKBN

19. Wilson A, Marshall J. A review of corneal biomechanics: Mechanisms for measurement and the implications for refractive surgery [Internet]. Indian journal of ophthalmology. U.S. National Library of Medicine; 2020 [cited 2023Apr22]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7856929/

20. Piñero, D. P., Alio, J. L., Barraquer, R. I., Michael, R., & Jiménez, R. (2010). Corneal Biomechanics, Refraction, and Corneal Aberrometry in Keratoconus: An Integrated Study. *Investigative Opthalmology & Visual Science*, *51*(4), 1948. https://doi.org/10.1167/iovs.09-4177

21. Kaushik S, Pandav SS. Ocular response analyzer [Internet]. Journal of current glaucoma practice. Jaypee Brothers Medical Publishers; 2012 [cited 2022Oct1]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5159455/

22. Satitpitakul, V., Taweekitikul, P., Puangsricharern, V., Kasetsuwan, N., Reinprayoon, U. and Kittipibul, T., 2021. Alteration of Corneal Biomechanical Properties in Patients with Dry Eye Disease. [online] PubMed Central. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8274861/ [Accessed 28 September 2022].

23. Garcia-Porta N, Fernandes P, Queiros A, Salgado-Borges J, Parafita-Mato M, González-Méijome JM. Corneal biomechanical properties in different ocular conditions and new measurement techniques [Internet]. ISRN ophthalmology. Hindawi Publishing Corporation; 2014 [cited 2022Sep11]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3960740/#B3

24. Tian L, Huang Y-F, Wang L-Q, Bai H, Wang Q, Jiang J-J, et al. Corneal biomechanical assessment using Corneal Visualization Scheimpflug technology in keratoconic and normal eyes. Journal of Ophthalmology. 2014;2014:1–8. Available from: https://www.researchgate.net/publication/262072513_Corneal_Biomechanical_Assessment_Using_Corneal_Visualization_Scheimpflug_Technology_in_Keratoconic_and_Normal_Eyes

25. Alkabbani S, Jeyaseelan L, Rao A, Thakur S, Warhekar P. The prevalence, severity, and risk factors for dry eye disease in Dubai – a cross sectional study [Internet]. BMC Ophthalmology. 2021 [cited 14 September 2022]. Available from: https://bmcophthalmol.biomedcentral.com/articles/10.1186/s12886-021-01978-4#citeas

Appendices

Appendix A:

Approval Letter from the University of the West Indies Campus Research Ethics Committee (with missing Co-investigator)

THE UNIVERSITY OF THE WEST INDIES
ST. AUGUSTINE, TRINIDAD AND TOBAGO, WEST INDIES
CAMPUS RESEARCH ETHICS COMMITTEE
TELEPHONE: (1-868) 662-2002 ext. 82755 E-mail: campusethics@sta.uwi.edu

November, 14 2022

Dr. Kingsley Ekemiri
Saarah Hosein, Abdullah Patel
Optometry Unit
Faculty of Medical Sciences
Email: kingsley.ekemiri@sta.uwi.edu

Dear Dr. Kingsley Ekemiri,

Ref: CREC-SA.1795/10/2022

Title: Variation of the corneal biomechanical properties of patients with dry eyes, keratoconus and healthy eyes using the ocular response analyzer machine.

I am pleased to advise that your application for research on the above captioned topic has been approved on behalf of Campus Research Ethics Committee, St. Augustine.

Approval is valid for one (1) year.

Sincerely,

Professor Jerome De Lisle
Chair
Campus Research Ethics Committee

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Appendix B:

Corrected Approval Letter from the University of the West Indies Campus Research Ethics Committee

THE UNIVERSITY OF THE WEST INDIES
ST. AUGUSTINE, TRINIDAD AND TOBAGO, WEST INDIES
CAMPUS RESEARCH ETHICS COMMITTEE
TELEPHONE: (1-868) 662-2002 ext. 82755 E-mail: campusethics@sta.uwi.edu

March, 24 2023

Dr. Kingsley Ekemiri
Saarah Hosein, Abdullah Patel, Ruqayya Juman
Clinical Surgical Sciences
Faculty of Medical Sciences
Email: kingsley.ekemiri@sta.uwi.edu

Dear Dr. Kingsley Ekemiri,

CREC-SA.1795/10/2022

Variation of the corneal biomechanical properties of patients with dry eyes, keratoconus and healthy eyes using the ocular response analyzer machine.

I am pleased to advise that your application for modification on the above captioned topic has been approved on behalf of Campus Research Ethics Committee, St. Augustine.

Approved modifications are as follows:

- addition of Ruqayya Juman as co-investigator

Approval is valid until October 2023.

Sincerely,

Professor Jerome De Lisle
Chair
Campus Research Ethics Committee

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Appendix C:

Consent Form given to every participant for data collection.

CONSENT TO PARTICIPATE IN RESEARCH

Research Title: Variation of the corneal biomechanical properties of patients with dry eyes, keratoconus and healthy eyes using the Ocular Response Analyzer machine.

I ……..hereby confirm that I voluntarily consent to participate in a research study entitled **Variation of the corneal biomechanical properties of patients with dry eyes, keratoconus and healthy eyes using the Ocular Response Analyzer machine.** I have been adequately informed of the purpose and procedure of the study by ……..

All information taken from the study will kept completely anonymous. I understand that there will be no cost incurred upon me by consenting to participate in this study. I declare that my participation in this study is entirely voluntary, and I may terminate my participation at any time. If I have any further questions/concerns or queries related to the study I understand that I may contact the principal investigator on **Kingsley.Ekemiri@sta.uwi.edu** or co-investigators at **ruqayya.juman@my.uwi.edu** , **saarah.hosein@my.uwi.edu** and **abdullah.patel@my.uwi.edu**.

If I have any questions or queries about my rights as a study participant, or if I am concerned about an aspect of the study or the researcher then I may contact: The UWI Research and Ethic Committee on **campusethics@sta.uwi.edu**

Date: _____.

I voluntarily agree to participate in this research program

□ **Yes**
□ **No**

I understand that I will be given a copy of this signed Consent Form.

Name of Participant (print): Signature: Date:
Name of Witness (print): Signature: Date:

Person Obtaining Consent:

Signature: Date:

Note: A copy of the signed, dated consent form must be kept by the Principle Investigator(s) and a copy must be given to the participant.

Regards,
Ruqayya Juman,
Saarah Hosein,
Abdullah Patel.
Research Student Co-Investigators,
Optometry Unit,
Department of Clinical Surgical Sciences,
Faculty of Medical Sciences,
University of the West Indies,
St. Augustine Campus.

Appendix D:

Questionnaire given to each participant before data collection for demographic data and to aid in placing the subjects in the correct study group.

Number: _____ Date:__/__/__ Sex: M F (Circle)
DOB: __/__/__ Ethnicity: _____

Circle or tick the answers that apply to you and write where necessary on the lines provided.

Section 1: Questions about general eye health

1. Do you have dry eye disease?
   Yes No

If yes, skip to section 2.

2. Do you have keratoconus?
   Yes No

If yes, skip to section 3.

3. Have you had a recent eye exam? If yes, what was the outcome?

_____

4. Do you currently experience any blurred vision, trouble reading or driving, double vision, pain in the eyes, flashes or floaters?

Yes No

If yes, please specify which symptoms:

_____

Section 2: Questions about dry eye (only applicable to persons with dry eye)

1. Select the symptoms you experience:

☐ Dryness or grittiness

☐ Burning or watering

☐ Eye Fatigue

2. Select the frequency of the symptoms you selected above:

☐ Constant

☐ Often

☐ Sometimes

3. Are the symptoms you selected:
☐ Tolerable: comfortable enough to not bother you throughout the day

☐ Bothersome: irritating and interferes with your day

☐ Intolerable: unable to perform daily tasks

4. Do you use eye drops for lubrication or relief?
Yes No

Section 3: Questions about keratoconus (only applicable to patients with keratoconus)

1. Have you been diagnosed with keratoconus?
Yes No

2. If you answered yes to question 1, at what age were you diagnosed?
_____

3. Are you aware of the stage of keratoconus you were diagnosed with? If so, what stage?
_____

4. Have you had cross linkage to slow the progression of your keratoconus?
Yes No

Appendix E:

Data Collection sheet for the Keratoconus eyes Group

Patients	AGE	KERATOCONUS EYES																					
		VA		ANGLES		Keratometry				TBUT						ORA							
						K Readings/mm		Grading of Keratoconus		TBUT (sec)		Schirmer Test (mm)		Grading of Dry Eyes		IOPcc / mmHg		IOPg / mmHg		CRF		CH	
		Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye
1	22F	20/200	20/40	4	4	6.32	7.13	stage 2	stage 1	8	8	15	17	Mild	Mild	10.4	12.9	8.3	10.3	7.7	7.7	9.8	9.1
2	20M	20/200	20/100-1	4	4	7.43	7.32	stage 1	stage 1	6	6	8	9	Moderate	Moderate	13	14.1	8.3	9.43	5.7	5.9	7.4	7.3
3	35F	20/59	20/100 +2	3	4	7.36	7.34	stage 1	stage 1	10	10	11	11	Mild	Mild	19.6	12.8	14	10.4	6	8	5.8	9.3
4	62F	20/59-1	<CF	4	2	7.43	4.93	stage 1	deformed	10	10	15	15	Mild	Mild	14.1	21.9	14.1	18.1	10.6	8.3	11.1	7
5	40M	20/59	20/40	4	4	7.55	7.41	stage 1	stage 1	10	10	16	18	Normal	Normal	13.8	11.7	13.7	13	10.4	11.4	11	12.4
6	36F	<CF	20/200	4	4	5.70	7.17	stage 3	stage 1	6	8	7	10	Moderate	Moderate	20.6	21.8	21	24.2	12.2	12.1	10.6	9.4
7	33F	20/40	20/40	4	4	7.10	7.16	stage 1	stage 1	8	9	12	15	Mild	Mild	11.9	13.7	9.3	10.7	7.6	7.4	9.2	8.6
8	18M	20/200	<20/200	3	4	6.30	5.84	stage 2	stage 3	10	10	19	17	Normal	Normal	16.1	12.5	10.2	8	5.1	5.8	6.1	7.6
9	65F	20/160	20/80	3	2	7.41	7.11	stage 1	stage 1	10	10	18	17	Normal	Normal	18.1	15	19.1	17.3	12.3	13	11.3	12.8
10	34M	20/40	20/32	4	4	7.82	6.71	stage 1	stage 1	10	10	12	11	Normal	Normal	14.7	16	12.4	13.6	7.2	8.5	7.1	8.9
11	35F	<20/200	<20/200	3	3	5.55	5.66	stage 3	stage 3	3	3	18	19	Severe	Severe	12.7	10.7	7.9	6.1	5.5	5	6.8	6.2
12	33M	20/50	20/80	3	4	7.73	7.61	stage 1	stage 1	5	4	10	10	Mild	Mild	12.5	16.9	10.8	15.8	8.6	10	9.9	9.8
13	33F	20/100	20/200	4	4	6.99	6.92	Stage 2	Stage 2	9	10	17	19	Normal	Normal	11	12.8	9.4	7.1	8.4	4.7	10.2	6.6
14	36F	20/40	20/60	4	4	7.21	7.18	Stage 1	Stage 1	9	8	15	13	Mild	Mild	13	14.2	10.1	11.3	7.5	7.7	8.9	8.7
15	30M	20/100	20/80	4	4	6.88	6.93	Stage 2	Stage 2	6	8	12	15	Mild	Mild	14	12.1	13.2	8.9	9.8	7.1	10.5	8.8
16	56M	20/50	<20/200	4	4	6.93	6.00	Stage 2	Stage 2	10	10	22	24	Normal	Normal	10.6	20.1	10.7	21.4	9.9	13	11.5	11.3
17	23F	20/100	20/80	3	3	6.31	6.48	Stage 2	Stage 2	10	10	20	19	Normal	Normal	13.3	13.2	10.2	9.4	7.4	6.7	8.7	8.1
18	46F	<20/200	20/100	4	4	6.45	6.93	Stage 2	Stage 2	4	6	9	12	Mild	Moderate	22.2	24.8	20.1	20.9	9.9	8.7	8.3	6.5
19	40M	20/40	20/100	4	4	7.21	6.89	Stage 1	Stage 2	10	10	15	18	Normal	Normal	15.7	15	12.3	11.5	7.5	7.3	8.2	8.2
20	27F	20/60	20/30	4	4	7.18	7.62	Stage 1	Stage 1	9	10	12	17	Moderate	Normal	13.8	13.1	11.5	11.1	6.7	8.4	7.4	9.5
21																							

Data Collection sheet for the Dry eyes Group

Patients	AGE	DRY EYES																					
		VA		ANGLES		Keratometry		TBUT								ORA							
						K Readings/mm		TBUT (sec)		Schirmer Test (mm)		Grading of Dry Eyes		IOPcc / mmHg		IOPg / mmHg		CRF		CH	
		Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye
1	20F	20/30	20/30	4	4	7.40	7.50	6	7	7	9	Moderate	moderate	9.3	8.2	10.3	9.8	10.6	11	12.4	13.1		
2	21F	20/20	20/20	4	4	7.90	7.80	6	7	6	8	Moderate	Moderate	18.9	19.3	22.8	23.2	15.3	15.3	13.5	13.5		
3	22M	20/20	20/20	3	3	7.90	7.90	6	6	10	10	Moderate	Moderate	10.5	11.1	10.4	10.8	9.7	9.7	11.4	11.2		
4	21F	20/20	20/20	4	4	7.90	7.80	5	6	6	7	Moderate	Moderate	13.5	13.4	14.5	13.6	11.4	11.3	12	11.3		
5	20M	20/20	20/30	3	4	7.80	7.80	5	4	4	4	Moderate	Moderate	17.1	13.9	16.8	13.9	10.7	10.4	10.3	11		
6	23F	20/20	20/20	3	3	7.50	7.60	7	5	10	8	Moderate	Moderate	14.8	11	12.9	9.7	8.7	8.6	9.4	10.4		
7	59F	20/40	20/63	3	2	7.80	7.80	5	4	7	5	Moderate	Moderate	20.4	15.2	20.4	15.3	11.8	10.9	10.2	11		
8	42M	20/40	20/40	3	3	7.90	7.90	3	3	3	5	Severe	Severe	12.9	14	13.8	13.6	11.1	10.1	11.8	10.8		
9	23F	20/40	20/30	4	4	7.32	7.30	7	6	10	11	Moderate	Moderate	11.6	8.7	14.2	11.7	12.6	12.4	13.4	14.1		
10	38F	20/25	20/25	3	3	7.85	7.35	3	3	3	5	Severe	Severe	14.3	14.6	12.2	12.4	8.5	8.5	9.3	9.3		
11	27F	20/200	20/200	4	4	7.80	7.65	7	6	15	15	Moderate	Moderate	13	16.5	11.4	17	8.7	10.7	9.9	10.2		
12	abdullah	20/40	20/40	4	4	7.75	7.22					Moderate	Moderate	16	18.2	17	14.7	11.9	7.9	11.6	7.7		
13	22F	20/25	20/25	4	4	7.80	7.90	6	6	5	5	Severe	Severe	16.7	15.1	16.7	13.6	11	9.3	10.7	9.8		
14	22F	20/200	20/200	4	3	7.65	7.70	7	5	9	10	Moderate	Moderate	14	17.8	16.3	16.6	12.7	10	12.8	9.6		
15	23F	20/40	20/40	4	4	7.90	7.80	6	5	12	10	Moderate	Moderate	11.6	10.4	13.2	12	11.6	11.3	12.6	12.7		
16	21F	20/25	20/25	4	4	7.65	7.55	8	7	13	12	Moderate	Moderate	17.3	16.9	20.7	19.6	14.5	13.7	13.3	12.8		
17	20F	20/20	20/20	3	4	7.60	7.70	6	6	11	11	Moderate	Moderate	16.9	12.2	19.6	18.5	13.7	16.3	16.3	12.8		
18	23M	20/20	20/20	4	4	7.56	7.44	5	5	8	6	Moderate	Moderate	15.6	15.2	15.5	15.8	10.7	11.4	10.8	11.4		
19	63M	20/40 +1	20/25 -1	1	2	7.57	7.49	2	4	2	3	Moderate	Moderate	11.9	9.7	9.1	11	7.4	10.9	9.1	12.6		
20	43F	20/20	20/20	3	4	7.88	7.35	5	5	11	12	Moderate	Moderate	16.3	11.3	17.7	16.4	12.3	13.4	11.9	13.6		
21	38M	20/40	20/40	3	4	7.73	7.77	7	7	15	15	Moderate	Moderate	22.4	18.5	21.4	16.8	11.2	11.5	9.2	11.3		
22	57F	20/30 -1	20/40	3	3	7.86	7.75	6	3	10	5	Moderate	Moderate	17.1	18.8	18.6	18.7	12.6	11.3	11.8	10.4		
23	23F	20/200	20/200	4	4	7.55	7.62	6	6	15	16	Moderate	Moderate	21.5	20.7	23.5	23.5	13.9	14.4	11.7	12.3		
24	27F	20/200	20/200	4	4	7.68	7.29	4	4	9	10	Moderate	Moderate	18.5	18.2	18.4	20.8	11.2	13.9	10.3	12.6		
25	22F	20/20	20/20	4	4	7.88	7.64	8	7	12	10	Moderate	Moderate	13.6	11.9	15.1	15.1	11.9	13.3	12.3	13.9		
26	21M	20/20	20/20	4	4	7.53	7.38	7	7	10	9	Moderate	Moderate	15.4	15.7	13.9	14.7	9.3	9.8	9.7	10		
27	65F	20/40 +1	20/59 +2	2	2	7.63	7.46	5	6	7	9	Moderate	Moderate	15.8	16.4	14.6	14.7	9.7	9.3	9.9	9.4		
28	21F	20/40	20/30	4	4	7.73	7.65	5	7	7	10	Mild	Moderate	16.4	14.8	16.1	13.9	10.6	9.8	10.4	10.3		
29	21F	20/20	20/20	3	4	7.86	7.66	4	6	10	13	Moderate	Moderate	11.8	13	11	11.1	9.3	8.5	10.7	9.7		
30	46F	20/50	20/100	3	3	7.81	7.59	5	4	10	6	Moderate	Severe	22.2	24.8	20.1	20.9	9.9	8.7	8.3	6.5		
31																							

Data Collection Sheet for the Healthy eyes Group

Patients	HEALTHY EYES																			
	AGE	VA		ANGLES		Keratometry		TBUT									ORA			
						K Readings/mm		TBUT (sec)		Schirmer Test (mm)		Grading of Dry Eyes		IOPcc / mmHg		IOPg / mmHg		CRF		CH	
		Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye
1	20F	20/20	20/20	4	4	7.67	7.61	10	10	24	23	Normal	Normal	13.4	12.3	16.8	17.8	13.8	15.2	13.9	15.4
2	21F	20/40	20/50	4	4	7.54	7.65	10	10	19	21	Normal	Normal	18.9	22	20.1	22.8	11.9	12.5	12	11.5
3	21F	20/20	20/20	4	3	7.75	7.71	8	9	35	28	Normal	Normal					10.1	11.3	10.1	11.5
4	22F	20/20	20/20	3	4	7.27	7.33	9	11	22	33	Normal	Normal	13.2	9.3	14.1	11.3	11.3	11.2	11.9	12.8
5	31M	20/100 +2	20/25	4	4	8.00	7.72	9	8	14	17	Mild	Normal	13.4	13.4	17.8	15.4	14.7	12.4	14.7	12.7
6	55M	20/30-1	20/30 -1	4	3	7.70	7.80	10	10	20	15	Normal	Mild	19.4	19.7	18.1	17.4	10.3	9.3	9.3	8.5
7	27M	20/32	20/25	3	2	7.60	7.63	10	10	17	18	Normal	Normal	17	12.9	17.7	14.2	11.7	11.6	11.2	12.3
8	21M	20/200	20/200	4	4	7.65	7.65	10	10	17	18	Normal	Normal	15.7	15.3	14.1	13.4	9.2	8.9	9.5	9.4
9	39M	20/40	20/60	4	4	7.35	7.55	10	10	25	25	Normal	Normal	18	17.1	21.6	19.3	14.9	13.2	13.5	12.4
10	20 M	20/25 +2	20/20	4	4	7.19	7.20	10	10	20	23	Normal	Normal	15	9.5	13.4	11.1	9.1	11.2	9.6	12.9
11	21M	20/25	20/25	4	4	7.45	7.55	10	10	27	30	Normal	Normal	11.3	17.4	13.3	16.8	12	10.6	13	10.2
12	60F	20/25	20/40	3	3	7.55	7.35	9	9	17	18	Normal	Normal	14.4	17.6	14.9	18.5	11.1	12.1	11.4	11.3
13	20F	20/20	20/20	4	4	7.65	7.70	10	10	21	20	Normal	Normal	16.1	14.4	19.3	15.7	14	11.9	13.3	12
14	54M	20/20	20/20	4	4	7.40	7.30	10	10	23	23	Normal	Normal	13.6	11.4	11.3	11.6	8.2	10.2	9.3	11.5
15	26F	20/20	20/20	3	4	7.38	7.44	10	10	19	20	Normal	Normal	14.3	12.1	14.6	11.5	10.9	9.6	11.3	10.8
16	20F	20/20	20/20	4	4	7.71	7.90	10	10	22	25	Normal	Normal	12.7	14.6	13.5	15.8	11.1	11.8	11.9	12
17	40F	20/25	20/20 +2	3	3	7.47	7.42	10	10	30	34	Normal	Normal	16.2	13.4	15.4	14.3	10.1	11.2	10.1	11.8
18	35F	20/20	20/20	4	4	7.55	7.42	10	10	20	21	Normal	Normal	12.8	14.8	10.4	13.3	7.9	7.8	9.3	8.7
19	25F	20/20	2/20	4	4	7.81	7.35	10	10	26	25	Normal	Normal	14.7	17.3	13.5	16	9.5	9.9	10.1	9.6
20	23F	20/20	20/20	3	3	7.50	7.60	10	10	22	20	Normal	Normal	11.3	11	10.4	11.4	9.1	10.3	10.7	11.7
21	59M	20/80 -2	20/59 -1	2	2	7.82	7.76	10	10	24	20	Normal	Normal	15.6	15.7	19.6	18.4	14.7	13.5	14	13
22	60F	20/40 -2	20/30	3	3	7.75	7.64	10	10	26	25	Normal	Normal	19.2	14.9	19.4	14	11.7	9.8	10.5	10.2
23	28M	20/25	20/25	4	4	7.88	7.52	10	10	21	20	Normal	Normal	22.2	20.5	18.9	17.7	8.8	9	7.4	7.9
24	21F	20/20	20/20	4	4	7.55	7.80	10	10	24	24	Normal	Normal	7	8.8	8.3	10.2	10.5	10.9	13	12.8
25	20F	20/20	20/20	4	4	7.71	7.85	10	10	21	22	Normal	Normal	13	13.6	14.3	11.9	11.6	8.8	12.2	9.8
26	21F	20/20	20/20	4	3	7.21	7.54	10	10	18	17	Normal	Normal	15.3	12.6	14.1	15.4	9.6	13	10	13.5
27	22F	20/20	20/20	4	4	7.22	7.57	10	10	20	19	Normal	Normal	13.3	12.7	14.8	13.2	11.8	10.8	12.3	11.6
28	55M	20/25	20/40	4	3	7.66	7.81	10	10	22	24	Normal	Normal	20.6	14.5	19	13.9	10.2	10	8.9	10.5
29	65F	20/25	20/30	3	4	7.61	7.73	10	10	23	25	Normal	Normal	15	17.7	14	16.3	9.7	9.8	10.1	9.5
30	21F	20/20	20/20	4	4	7.77	7.68	10	10	20	24	Normal	Normal	13.3	14.1	12.2	15.4	9.3	11.7	10.3	12
31	20F	20/40	20/30	4	4	7.86	7.89	10	10	19	22	Normal	Normal	18.7	17.4	17.8	15.3	10.6	9.1	9.8	8.9
32	25F	20/20	20/20	4	4	7.26	7.88	10	10	21	20	Normal	Normal	19.4	15.5	22.6	19.9	14.7	15.1	12.9	13.7
33	36F	20/100	20/200	3	4	7.55	7.63	10	10	22	25	Normal	Normal	22	17	17.7	17	7.8	11.1	6.6	10.7
34	22M	20/20	20/25	4	4	7.44	7.47	10	10	24	25	Normal	Normal	14.7	11.8	16.7	12.2	12.6	10.5	12.5	11.6
35	31M	20/20	20/20	4	4	7.66	7.65	10	10	20	19	Normal	Normal	15.1	15.6	12.1	13.5	9.2	9.5	8.9	9.1
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