

CORRELATION BETWEEN CORNEAL ASTIGMATISM AND CORNEAL TOPOGRAPHIC INDICES IN EARLY KERATOCONUS FOR EARLY DETECTION AND MANAGEMENT

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ABSTRACT

Objective: The Objective of this study is to find the correlation between the corneal astigmatism and corneal topographic indices in early keratoconus for early detection and early management.

Methodology: It was a prospective cross-sectional study which was conducted among the patients aged 5-25 years with moderate to high astigmatism like 2DC or greater. Approximately 70 eyes were selected using non-probability sampling technique. Corneal Topographic and tomographic parameters were assessed to identify early keratoconus and their relationship with astigmatism was evaluated. Data was analyzed by using SPSS, with descriptive statistics, comparison of the parameters like corneal astigmatism, flat keratometric value K1, Steep keratometric value (K2), maximum keratometric value (Kmax), Thinnest pachymetry point thickness (TCT), central corneal thickness (CCT), Posterior Elevation (PE) among keratoconus-status groups, and correlation analysis between corneal astigmatism and other indices including K1, K2, Kmax, TCT, CCT, PE and keratoconus status.

Major findings: The keratoconus-suspect group was the largest group, comprising 29 eyes (41.4%), followed by the keratoconus-present group with 21 eyes (30.0%). Twenty eyes (28.6%) had no keratoconus. A significant differences was found among the keratoconus-status groups for K1 ($p=0.001$), for K2 ($p < 0.001$), for Kmax ($p=0.009$), for corneal astigmatism ($p=0.020$), and for TCT ($p < 0.001$). Corneal astigmatism showed significant correlations with K2 ($p < 0.001$), Kmax ($p < 0.001$), TCT ($p = 0.009$), CCT ($p = 0.003$), and with posterior elevation ($p = 0.029$), but not with K1 ($p = 0.251$).

Conclusions: Corneal astigmatism was significantly associated with several corneal tomographic and topographic parameters, particularly K2, Kmax, TCT, CCT, and posterior elevation. The findings of this research suggest that corneal astigmatism could be a useful indicator for identifying early changes suggestive of keratoconus.

KEYWORDS: Keratoconus, High Astigmatism, Corneal Topography, Corneal topographic indices, Scheimpflug tomographer, Early Keratoconus Indication.

INTRODUCTION

Keratoconus is an asymmetric, non-inflammatory, ectatic and progressive disorder of the cornea that is associated with degenerative and dystrophic changes within the corneal tissue. It is characterized by progressive thinning of cornea and cone-like development of cornea, resulting in forward protruded corneal surface, uneven corneal curvature manifests as irregular astigmatism, which ultimately can cause subsequent impairment of visual function. In keratoconus, axial protrusion of the cornea occurs along with stromal thinning and alterations in the biomechanical properties and structural organization of corneal collagen. These changes gradually contribute to the development of the characteristic conical corneal shape and result in myopia and irregular astigmatism. The collagen fibrils within the protruding region of the cornea also demonstrate an abnormal arrangement, further contributing to the structural changes associated with the disease. (1) Keratoconus is generally considered a bilateral but asymmetric condition; therefore, when signs of keratoconus are detected in one eye, the fellow eye may also be considered affected despite the absence of clinically visible pathological changes. In such cases, the fellow eye may represent a subclinical form of keratoectasia, in which early corneal changes are present without obvious clinical manifestations

Astigmatism is a type of refractive error where parallel rays of light does not focus onto a single point on the retina. Total corneal astigmatism represents the combined effect of astigmatism arising from both anterior and the posterior surfaces of cornea. Astigmatism can be classified in several ways, with the most common classification being irregular and regular astigmatism. In case of regular astigmatism, the flattest and the steepest corneal meridians are perpendicular to each other. However, in case of irregular astigmatism, the flattest and the steepest meridians are not perpendicular, with an angular difference of less than 90°, resulting in an irregular optical surface. Consequently, it becomes difficult to obtain a clear retinal image through simple cylindrical correction applied along a single meridian. (2)

The exact etiology of keratoconus remains incompletely understood, although several genetic, biochemical, and physical pathways have been suggested in its development. These factors may contribute to alterations in the corneal collagen fibers, leading to progressive stromal thinning and cone-shaped corneal protrusion. There is a suggestion of approximately 8% to 10% of keratoconus cases with positive family history. Chronic vernal keratoconjunctivitis is also considered to be associated with KC. (3) In the patients with VKC, in response of frequent rubbing of eyes, levels of inflammatory mediators like matrix metalloproteinase-13, tumor necrosis factor- α and interleukin-6 can increase in tears, including. These inflammatory changes can contribute to the onset and progression of KC (4)

In previous studies it has been reported that the prevalence of KC in general population is approximately 1 in 2,000 individuals. However, the reported incidence of the disease varies among different populations, which may be influenced by ethnic, environmental and genetic factors. KC may present as an isolated corneal disorder or may be associated with other systemic conditions like Ehlers–Danlos syndrome, Marfan syndrome, Osteogenesis imperfecta and Down syndrome. Although several gene polymorphisms have been suggested to have an association with keratoconus, but for the development of the disease no specific polymorphism which is directly responsible has yet been identified, and genetic investigations are still ongoing. The increasing availability and widespread use of corneal topography are also expected to result in the identification and reporting of higher prevalence and incidence rates. It is considered that the keratoconus commonly begins during adolescence and may continue to increase into the 3rd and 4th decades of life. Both males and females appear to be affected by the condition at relatively similar rates, with no consistent significant difference in occurrence between the two genders. (5)

When keratoconus begins during childhood, it tends to progress more rapidly than when it develops during adolescence or adulthood and therefore at the time of diagnosis may be detected at an advanced stage. Pediatric keratoconus is considered more aggressive, with a higher rate of disease progression compared with adult keratoconus, which may be related to the dynamic structural and biomechanical characteristics of the developing cornea. (6). In comparison with adult-onset of this disease, the major distinguishing feature for pediatric keratoconus is its relatively rapid progression. Several studies have demonstrated that the progression of KC occurs more frequently and at a faster rate in patients with the age less than 18 years and eventually these patients suspected seven-fold times greater chance of having the need of corneal transplantation in future. (7) Children having KC mostly present with advanced stage of disease and much deterioration in vision, primarily because of the association with myopia and irregular astigmatism. Consequently, poor visual functions during childhood can have important effects on their educational development, social interaction, mental well-being and overall quality of life. El-Khoury et al. reported an incidence in Lebanon that (0.53%) among the children with age 14 years or less, were diagnosed with KC at a tertiary referral eye center. Similarly, in southwestern Nigeria a study was conducted reported that the prevalence of blindness was (0.08%) due to keratoconus among school-aged children. More recently, a study conducted at Saudi Arabia reported that the prevalence of KC was (4.79%) among the pediatric population. These findings demonstrate variation in the reported occurrence and visual impact of pediatric keratoconus across different populations. (8)

Several factors have been associated with the progression of keratoconus, particularly habitual eye rubbing and allergic ocular conditions such as VKC which is a allergic inflammatory disorder which is chronic in nature, involving bulbar and tarsal conjunctiva and is commonly associated with intense ocular itching and excessive mucoid discharge. The occurrence of keratoconus during childhood and adolescence is often associated with high and irregular astigmatism; however, may have delayed diagnosis because detailed ocular examination can be challenging in younger patients. Furthermore, systemic conditions like Trisomy 21 have a recognized association with keratoconus, but developmental and intellectual disabilities may cause further complication in the detection of early corneal changes. (9)

Clinically, KC is typically recognized by irregular, high and progressive astigmatism, which may be asymmetric between the two eyes. Therefore, progressive deterioration of irregular astigmatism accompanied by a reduction in visual acuity should raise suspicion of underlying keratoconus and warrant further corneal assessment. The signs and symptoms of KC vary depending on the severity and stage of the disease clinically. On the slit-lamp examination, characteristic findings include protrusion and thinning of the inferior cornea, along with a fleischer ring which is a subepithelial deposition of pigmented compounds containing chalcophilic metals, particularly iron, zinc, and copper located around the base of the corneal ectasia. It may appear as a complete ring or, more commonly, as an arc or semicircular deposit in the inferior portion of the cornea. Another characteristic finding is Vogt's striae, which appear as fine vertical lines within the stroma of cornea at the apex of the ectasia. These Vogt's striae are thought to result from stretching and structural distortion of the corneal stroma, with associated cracks

or folds involving the Descemet's membrane in the area of corneal protrusion and the posterior stromal tissue. When a gentle pressure is applied on the cornea, these striae may get reduce or disappear. Other slit-lamp findings associated with keratoconus include the "fading star" or "fireworks" symptom, which may be observed because of structural changes within the cornea. Rarefaction of the corneal stroma may occur in the region of developing ectasia and can appear as corneal inhomogeneity or grayish opalescence, reflecting disruption of the normal organization of collagen lamellae within the anterior corneal stroma. Focal corneal thinning is another characteristic finding and is typically located at the apex of the ectatic protrusion, which may be situated in the central or paracentral cornea. Prominent stromal corneal nerves may also be observed because of increased visibility of the corneal nerve fibers. In more advanced disease, corneal turbidity and scarring can develop at the apex of the protrusion and may involve the epithelial, subepithelial, or stromal layers. These opacities and scars may result from edema and fibrotic changes within the corneal tissue caused by marked disruption of the architecture of the stretched stroma. In severe cases, ruptures or "cracks" in the Descemet's membrane may occur, which allow aqueous humor to enter in the corneal stroma and results in acute swelling of cornea or hydrops (10). Corneal scarring may also be associated with the inappropriate and prolonged use of rigid gas-permeable (RGP) contact lenses. Other sign of KC may include irregular mires during keratometry and the characteristic scissor reflex on retinoscopy, also described as "shadow whirling" or a "folding shadow." The scissoring reflex is produced by the irregular movement of the reflected light reflexes and shadows and is associated with the development of irregular astigmatism which is caused by changing in normal architecture and curvature of the cornea.

Other examination findings may be observed in patients with keratoconus at different stages of the disease. Munson's sign is characterized by a V-shaped configuration of the lower eyelid margin when the patient looks downward, resulting from the protruding cornea. Rizzuti's symptom can be demonstrated by directing a focused light toward the eye from the temporal side in the frontal plane. A light reflex may then be observed on the nasal side of the sclera due to the abnormal deflection of light toward the base of the cornea, which occurs as a result of the altered optical properties of the ectatic cornea. (11) Understanding the epidemiology of keratoconus is very important for development of appropriate screening strategies and facilitating early detection and early management of the disease.

Subclinical keratoconus is a specific condition considered as an early form of the disease where the characteristic clinical findings on SLE, keratometry, and retinoscopy are not yet present. Because these conventional clinical signs may be absent, identifying subclinical cases can be particularly challenging, making the appropriate selection and interpretation of diagnostic parameters essential. Moderate and severe forms of keratoconus are generally easier to recognize because they demonstrate characteristic clinical signs and recognizable topographic abnormalities. In contrast, subclinical keratoconus, in which the cornea may initially appear topographically unremarkable but subsequently develops changing towards ectasia, becomes a significant challenge to diagnose. Early keratoconus identification, particularly during its subclinical stage, is important for improving for the safest corneal refractive surgery and facilitating timely intervention. Detecting the disease at an early stage may also help prevent or limit further progression of corneal ectasia and associated visual impairment. (12)

Treatment options for KC vary according to the stage and severity of the disease and may include glasses, contact lenses (CLs), corneal cross-linking (CXL), and keratoplasty. Glasses and contact lenses are generally used to correct the refractive changes and improve visual function, whereas corneal cross-linking is aimed at stabilizing the cornea and slowing or halting disease progression before the development of advanced-stage disease. (13) CXL has also been reported to improve visual acuity (VA) in patients with KC and is FDA approved for pediatric, young and aged patients. Although corneal cross-linking has an important role in preventing or slowing progression of KC. Disease progression has also been reported in some patients following standard cross-linking treatment. Therefore, timely diagnosis of K has important clinical benefits, like progressive disease can be treated before reaching advanced stages characterized by complications such as dense corneal scarring, severe corneal thinning and acute corneal hydrops. (14) Early recognition and appropriate intervention may consequently help preserve corneal structure and visual function. Some previous studies have also reported a earlier onset and higher incidence of keratoconus among populations of Middle East, emphasizing the importance of early detection and appropriate management in these populations.

It is important to understand the epidemiology of keratoconus for developing the appropriate screening strategies and planning programs aimed at its early detection. However, the epidemiology of early or subclinical keratoconus has not been extensively addressed in the available literature. The limited evidence concerning subclinical keratoconus, with astigmatic errors, highlights the need for further investigation of its prevalence and early detection.

The diagnosis of KC is generally straightforward in advanced stage when characteristic clinical signs and typical corneal changes are clearly present and can be find and investigated through routine ophthalmic examination. However, detection of the keratoconus during its early stages, particularly when the condition has a non-progressive or low progressive course that can be considerably more challenging. At this stage, conventional clinical findings may be worsened or absent, making accurate diagnosis and identification of early corneal abnormalities much more difficult.

In the diagnosis of keratoconus, Placido disk-based corneal topography is widely used; however, when used alone, it has limited value in detection of subclinical cases because definitive abnormalities may not always be present.

(15) Patients may have relatively normal visual acuity and unremarkable slit-lamp findings at the subclinical stage, making clinical examination alone insufficient for reliable detection. Therefore, a comprehensive evaluation of corneal topographic and tomographic indices is important, as these techniques can find subtle alterations in corneal curvature, thickness, and surface regularity that may not be identified during routine examinations. Recognition of these early changes can facilitate the identification of patients at risk and support timely management of keratoconus. Over several decades, extensive research into the diagnosis, treatment, and correction of keratoconus has resulted in significant changes in the terminology and classification of the disease. In parallel, the criteria used for patient assessment and management have been repeatedly modified in accordance with evolving clinical requirements and advances in diagnostic and therapeutic technologies (16). Various corneal topography and tomography systems have been developed for the monitoring and diagnosis of KC. Among these, Pentacam HR (Oculus Optikgeräte GmbH, Wetzlar, Germany) with a rotating Scheimpflug camera and a monochromatic slit-light source to obtain 100 slit images through 360° has been a widely used investigation system that. The images are captured within approximately 2 seconds and provide data from about 25,000 elevation points, allowing a 3-D representation generation of the anterior segment (AC) and cornea. (17) In addition to elevation data, Pentacam provides quantitative measurements of the curvature of both the anterior corneal surface and posterior corneal surfaces and of corneal pachymetry. Its measurements of corneal thickness and posterior elevation have demonstrated good reproducibility and repeatability. The diagnostic value of Pentacam lies in its ability to provide detailed quantitative information about corneal curvature, elevation, and thickness, which can assist in distinguishing normal corneas from those with keratoconic changes. (18)

For Scheimpflug-based Pentacam, normal values indices have been reported in healthy eyes, providing reference ranges for evaluating corneal morphology. The relationship between the maximum pachymetric progression and thinnest corneal thickness can be evaluated by Ambrósio's relational thickness maximum (ARTmax) by providing information about the distribution of corneal thickness. (CAIRO 8) is an integrated parameter that incorporates relational corneal thickness together with other Pentacam-derived measurements within the 8-mm corneal zone from relational thickness between the corneal assessment index and other OCULUS values for the zone of 8-mm. Because structural changes associated with keratoconus may involve the posterior corneal surface (PCE), Scheimpflug tomography has been suggested as a useful method for KC identification in eyes that appear normal on conventional corneal topography. The Pentacam system, provides with at least eight indices available in software with version (1.19r11); however, these individual indices have the diagnosing ability in genuinely subclinical keratoconus has not been fully established. This is particularly relevant in clinical situations in which a patient may demonstrate an abnormal result in only one or two keratoconus-related parameters, requiring interpretation of the findings in the context of the remaining measurements.

Previous investigations have been focused primarily on selected components of the pentacam (Belin–Ambrósio enhanced ctasia display), differed in their definitions of subclinical keratoconus. Further evaluation of abnormal indices of individual pentacam in strictly subclinical cases is therefore important for understanding their contribution to the assessment. (20)

The purpose of my study is to find the early indication of early keratoconus and keratoconus-suspect among patients between the 5–25 years of age having an astigmatic refractive error of 2 or greater than 2 diopters (D)

1.1 AIM AND OBJECTIVES

The objective of this study is to find the correlation between the corneal astigmatism and corneal topographic and tomographic indices in early keratoconus for early detection and early management.

1.2 HYPOTHESES

1.2.1 Null Hypothesis (H_0):

No significant correlation present between corneal astigmatism and corneal topographic and tomographic indices in patients with early Keratoconus.

1.2.2 Alternative Hypothesis (H_1):

A significant correlation is present between corneal astigmatism and corneal topographic and tomographic indices in patients with early keratoconus.

RESEARCH METHODOLOGY

3.1 Research design:

A Prospective cross-sectional research design was selected.

3.2 Place of Study:

This study was conducted at Gujranwala Medical College teaching Hospital

3.3 Study Population:

Population of study was the Patients clinically diagnosed with early keratoconus aged 5–25 years and the astigmatic Patients with high cylindrical power greater than or equal to 2.00.

3.4 Sample Size Calculation:

The sample size was calculated by using Cochran's formula:

$n = Z^2 \times p \times (1 - p) / d^2$ Where:

$Z = 1.96$ (at 95% confidence level)

p = prevalence = 0.048

d = 0.05(as margin of error)

by putting the values

n = 70.21 Thus, the calculated sample size was approximately 70 eyes.

3.5 Sampling Technique:

This research used a non-probability convenient sampling technique for the participant selection process.

3.6 Selection criteria

3.6.1 Inclusion criteria

- I. Individuals with cylindrical refractive error equal or greater than 2 DC
- II. Individuals between the Age 5-25.
- III. Both male and female
- IV. Individuals with best corrected visual Acuity (BCVA) 6/6 (for distance) on Snellen Chart and N.6 on Near Vision Chart.

3.6.2 Exclusion criteria

- I. Individuals having Simple Spherical refractive error or having cylindrical refractive error < 2 DC,
- II. Patients with corneal dystrophy, corneal opacity, or keratitis of any type.
- III. Individuals with any past or present ocular pathology like Glaucoma, cataract, Diabetic Retinopathy etc
- IV. Individuals with history of previous ocular surgery,
- V. And of Age less than 5 years and above 25 years of age.
- VI. Individuals have history of previous ocular injury or trauma,
- VII. Individuals With dry eye disorders

3.7 Data collection instruments

- I. Autorefractometer, Keratometer, Ophthalmoscope, Retinoscope,
- II. Trial box with trial frame and Trial lenses, Snellen vision Chart and Near vision Chart.
- III. Slit Lamp Biomicroscope (Ziess SL 220)
- IV. Fluorescein Sodium Strips (Optiglo)
- V. Pentacam Corneal Topographer (Oculus Optikgeräte GmbH, Wetzlar, Germany)

3.8 Research tool

This research was carried out by Self Structured Examination based perfforma.

3.9 Data collection Procedure

The study was conducted as a cross-sectional observational study which involved the individuals having high astigmatism and were suspected for early keratoconus. Each participant in this study was subjected to general eye assessment included history taking (age, gender, history of glasses, any present or any past surgical history, medical history, history of injury or trauma, and history of usage of contact lens if they are contact lens user). Moreover before moving on corneal topography a thorough eye examination was done which include slit lamp biomicroscopy to examine the cornea, uncorrected visual acuity, cycloplegic refraction and best corrected visual acuity, and detection of any abnormality in the whole eye structure). Corneal astigmatism was measured using standard keratometry, which determines the of the anterior corneal curvature and quantifies astigmatism in diopters (D). In addition advanced imaging systems like Pentacam or Scheimpflug tomography were used to find corneal topographic and tomographic indices. Certain parameters were recorded from the Pentacam maps including Topographic astigmatism, K1, K2, Kmax, thinnest location thickness (TCT), central corneal thickness (CCT), and Posterior elevation (PE). The indication of keratoconus identified depended on presence of following pentacam derived criteria of keratoconus:

1. Kmax value greater than 48 diopters.
2. Corneal thinning (TCT) coinciding with steepest corneal point in relation to central corneal thickness
3. Increased posterior surface elevation more than 18 μ at the central 6 mm zone.

Pentacam images were obtained by a single operator and data analysis for keratoconus diagnosis was performed by the same ophthalmic trained Person. Correlation analysis was used to determine whether high astigmatism is associated with early changes in corneal shape, thereby provided insights into early detection and management strategies for keratoconus.

OCULUS - PENTACAM 4 Maps Refractive

1.22609

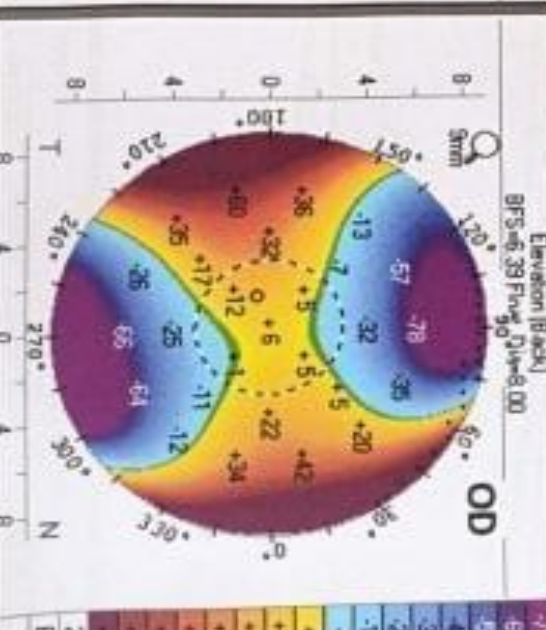
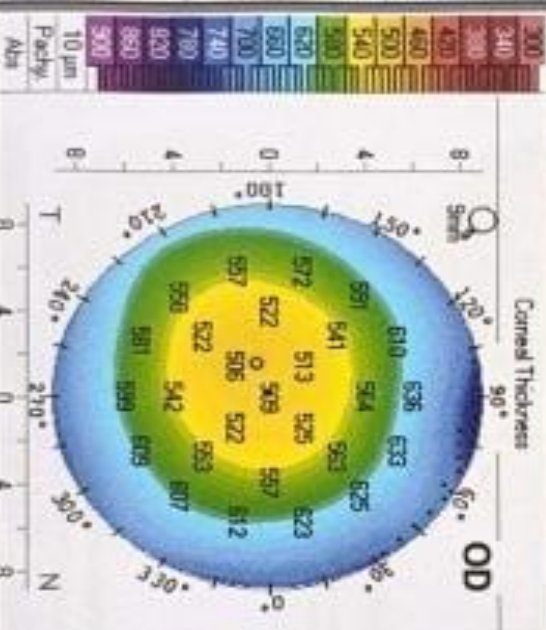
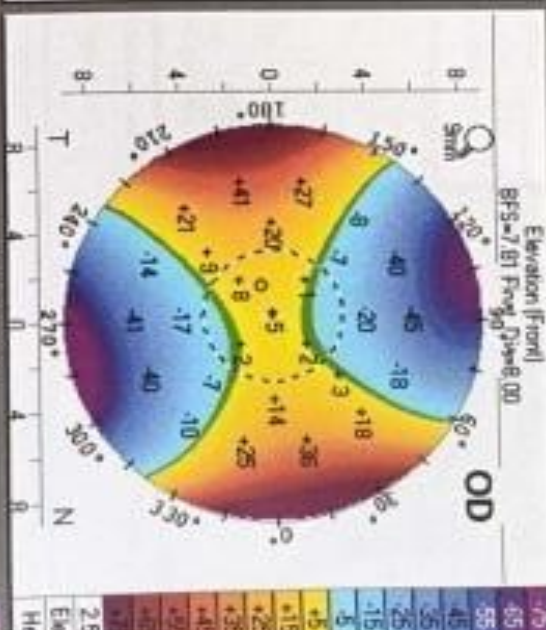
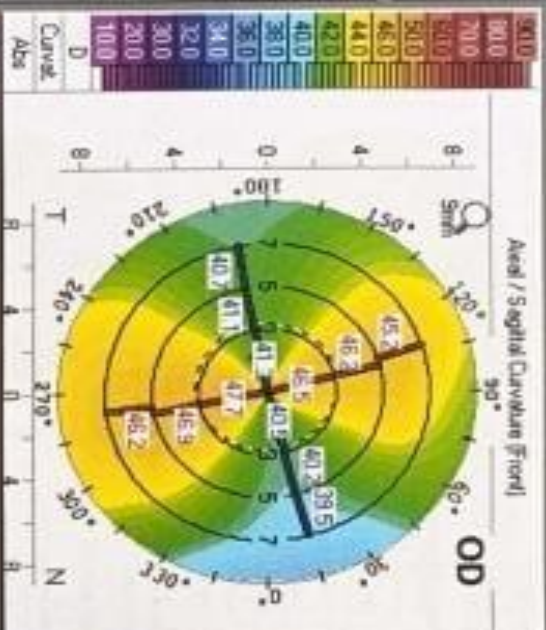
Last Name: LAVER
 First Name: Liv
 Date of Birth: 1994
 Exam Date: 21/02/2020
 Exam Info: 1

Cornea Front
 Rht: 8.24mm K1: 40.50
 Rv: 7.15mm K2: 47.20
 Rht: 7.70mm Km: 43.50
 Qs: OK (R) Astig: E.20
 E: 0.31 Rpe: 7.95mm Power: 7.07mm
 [207]

Cornea Back
 Rht: 6.67mm K1: 5.80
 Rv: 5.75mm K2: 7.10
 Rht: 6.31mm Km: 6.30
 Qs: OK (R) Astig: 11.10
 E: 0.11 Rpe: 6.68mm Power: 5.55mm
 [207]

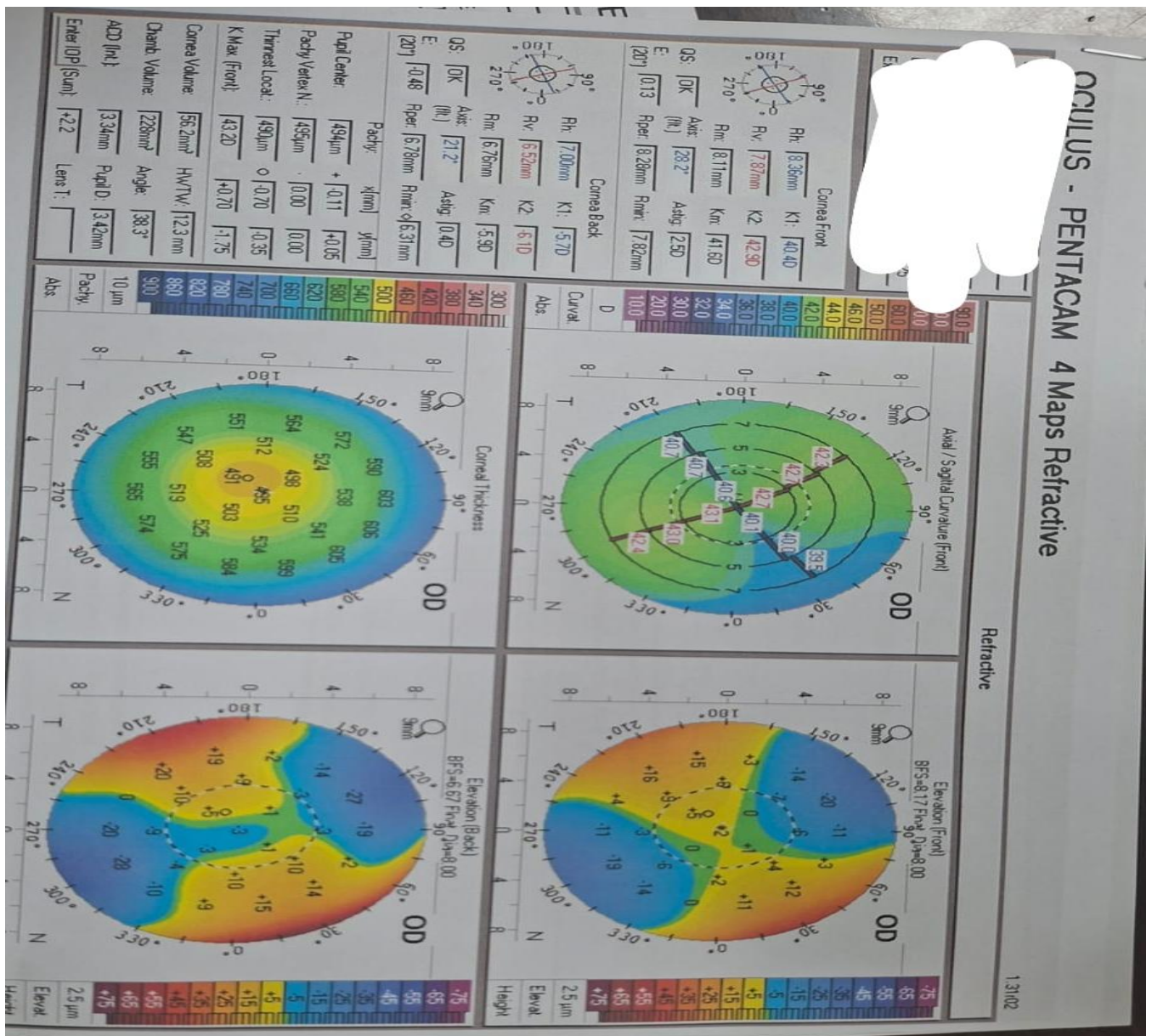
Pupil Center: 500µm + 0.13 -0.02
 Pachy Apex: 505µm 0.00 0.00
 Thinnest Locat: 504µm 0 0.02 0.27
 K Max (Front): 48.10 +0.07 -0.62
 Cornea Volume: 98.3mm³ HWTW: 1
 Chamber Volume: 129mm³ Angle: 30.0°
 ACD (Ht): 2.52mm Pupil D: 3.00mm
 Effective Power (Sun): +1.5 Lens T: 1

Refractive



3.10 Figure 1

Pentacam report of moderate astigmatic right (OD) eye with early indication of keratoconus indication
3.11 Figure 2



Pentacam report of high astigmatic left (OS) with no keratoconus indication

3.10 Data analysis method

SPSS statistical software version 26.0 was used for input and analysis of the collected data. Data including Age, Gender and corneal astigmatism Flat keratometric value K1, Steep keratometric value K2, Maximum corneal curvature Kmax, pachymetry thinnest point thickness TCT, Central Corneal thickness CCT and Posterior elevation PE were first entered into Microsoft Excel. Descriptive statistics, comparison of these parameters among keratoconus-status groups, and correlation analysis between corneal astigmatism and these indices was done by SPSS

3.11 Ethical considerations

The research subjects' rights were respected throughout the study, following the guidelines set by Superior University's ethics committee in Lahore.

- All participants provided written informed permission with a confidentiality agreement, and all information and data gathering were kept private.
 - All of the study's participants' identities were kept secret.
 - The participants were advised that the study's procedures had no risks or drawbacks.
 - Additionally, they were told that participants may leave the research at any point while it was still ongoing.
- Data was stored in a secure location with a lock and key in hand. Also It was password-protected on the laptop.

3.12 Rationale for the selected research design

Keratoconus is a progressive corneal disorder that often begins subtly, making early detection difficult. Corneal topography provides indices that can detect structural changes before clinical signs appear. Corneal astigmatism may reflect these early changes, but the relationship between astigmatism and topographic indices in early keratoconus is not well studied. Understanding this correlation can aid in early diagnosis and timely management, preventing disease progression and vision loss.

DATA ANALYSIS AND RESULTS

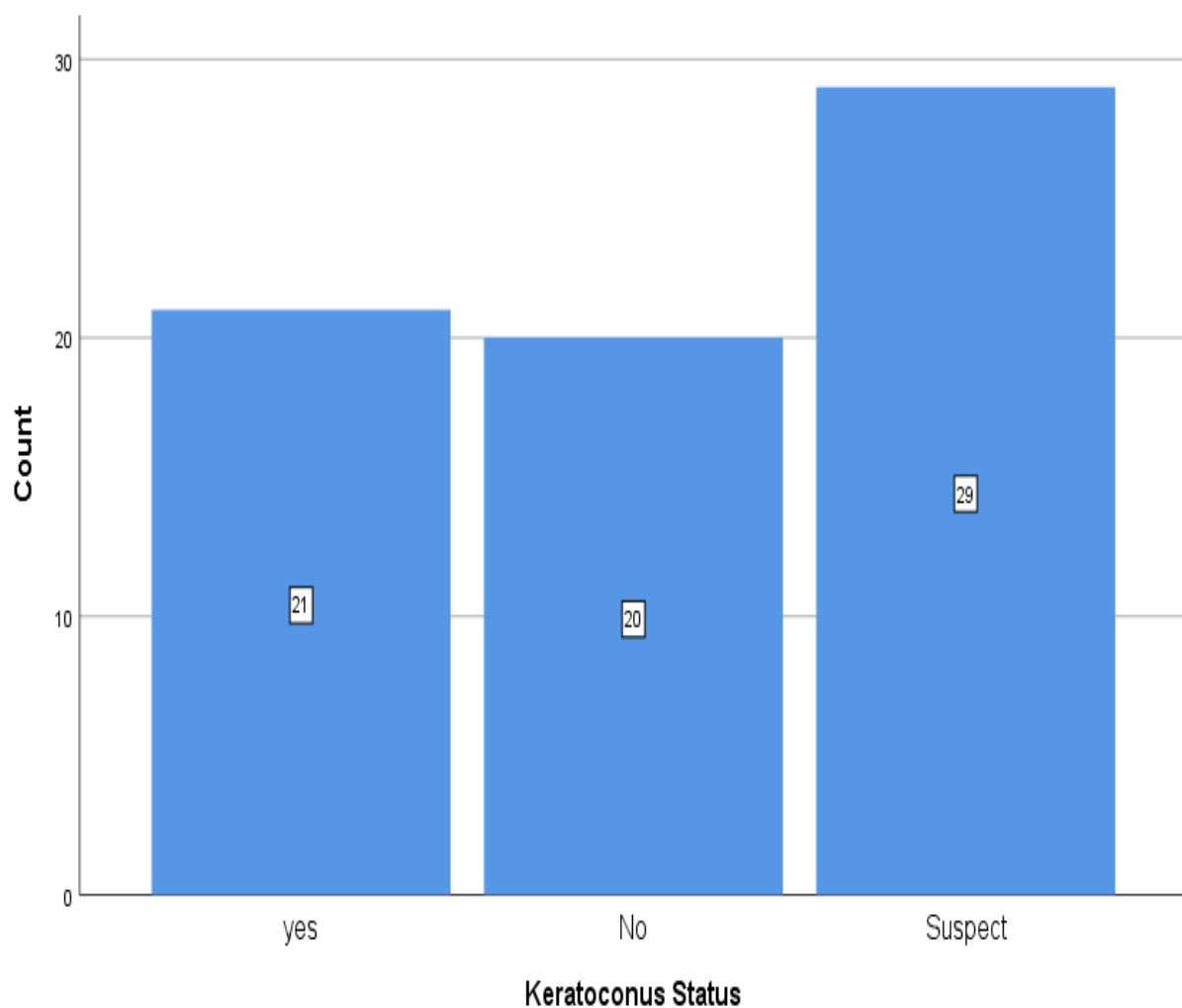
4.1 Distribution of Keratoconus Status

4.1.1 Table 1

The distribution of keratoconus status among the 70 studied eyes

Keratoconus Status	Frequency (n)	Percentage %
Yes	21	30.0
Suspest	29	41.4
No	20	28.6
Total	70	100

4.1.2 Graph 1



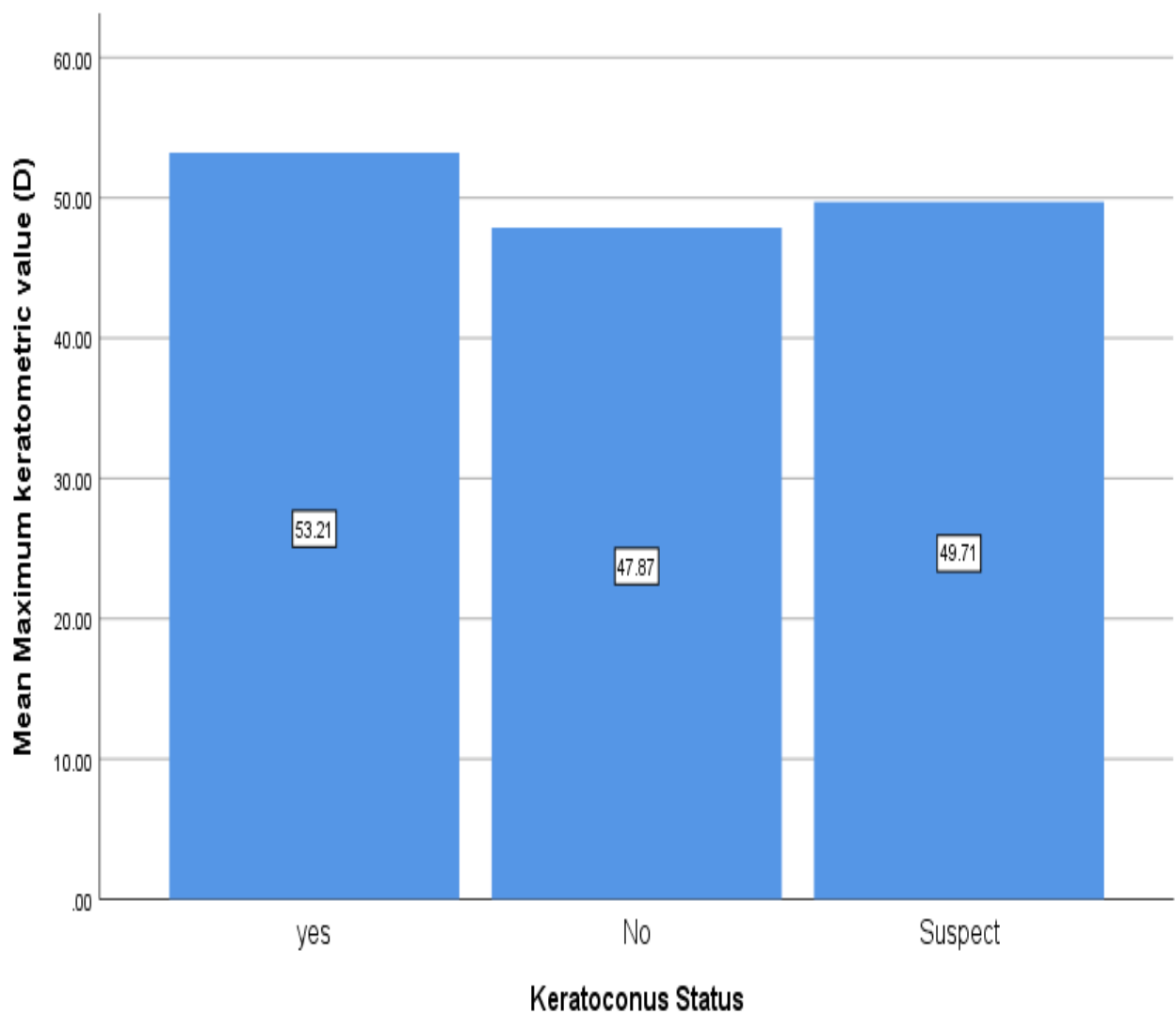
Comparison of Corneal Parameters Among Keratoconus Groups

4.2 Comparison of Corneal Parameters Among Keratoconus Groups

4.2.1 Table 2:

Comparison of all included corneal parameters among three keratoconus groups

Corneal Parameters	Suspect (n=29) Mean $\pm$ SD	Yes (n=21) Mean $\pm$ SD	No (n=20) Mean $\pm$ SD	p-value
Flat keratometric value, K1 (D)	44.54 $\pm$ 3.40	47.32 $\pm$ 4.58	43.20 $\pm$ 2.05	0.001
Steep keratometric value, K2 (D)	48.13 $\pm$ 3.96	51.87 $\pm$ 5.02	46.62 $\pm$ 1.93	<0.001
Maximum keratometric value, Kmax (D)	49.71 $\pm$ 6.18	53.21 $\pm$ 5.72	47.88 $\pm$ 3.98	0.009
Power of Astigmatism (D)	3.86 $\pm$ 1.47	4.58 $\pm$ 1.76	3.26 $\pm$ 1.14	0.020
Pachymetry thinnest point thickness (μ m)	473.28 $\pm$ 33.09	431.24 $\pm$ 51.59	531.75 $\pm$ 65.01	<0.001
Central corneal thickness (μ m)	487.52 $\pm$ 32.23	454.19 $\pm$ 49.14	529.70 $\pm$ 22.47	<0.001
Posterior Elevation (μ m)	15.21 $\pm$ 19.14	18.95 $\pm$ 18.08	8.75 $\pm$ 9.95	0.149



4.2.2 Graph 2

Comparison of corneal parameter kmax among the three groups.

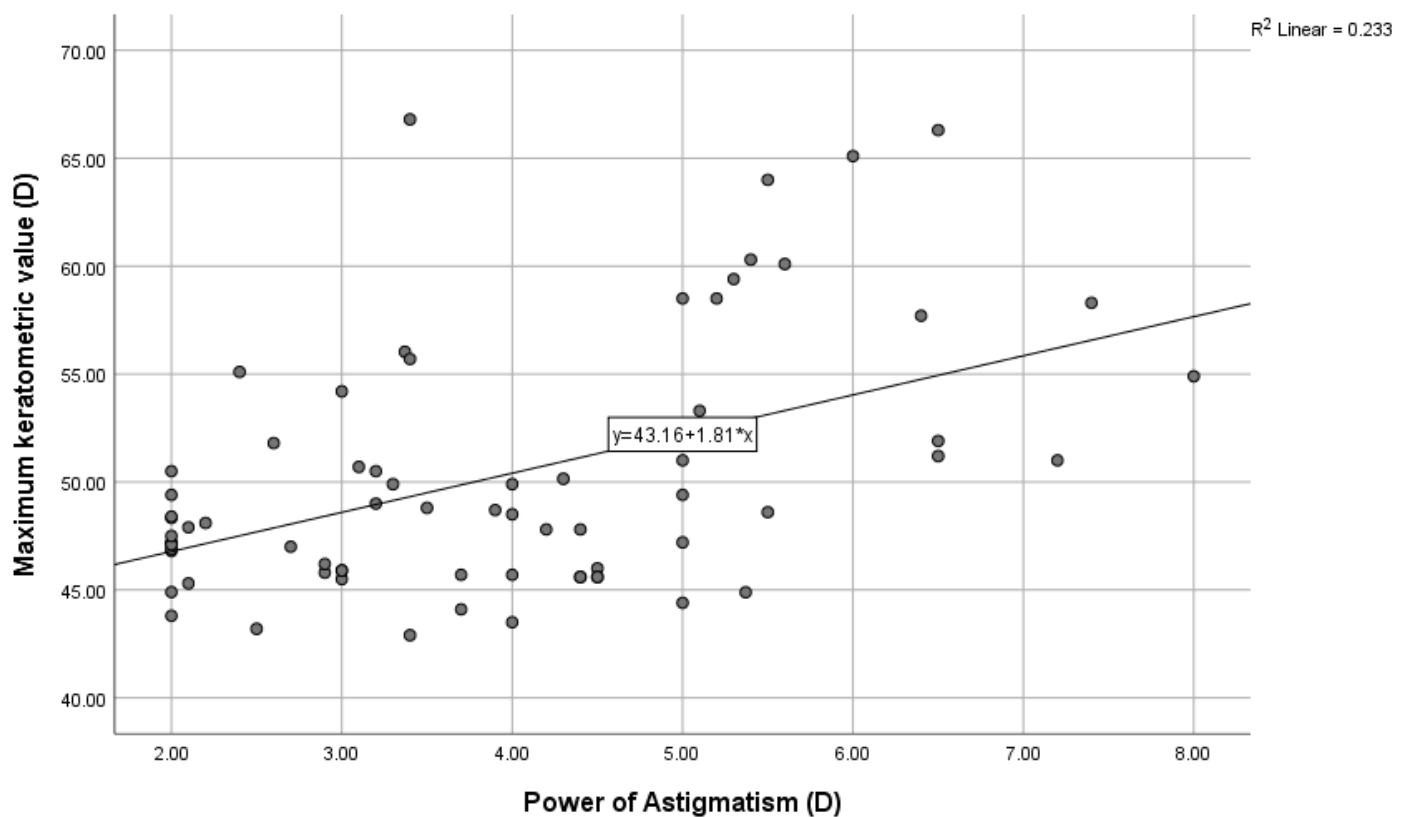
4.3 Correlation Between Corneal Astigmatism and Tomographic Parameters

4.3.1 Table 3

Correlation between corneal astigmatism and corneal tomographic parameters

Tomographic parameter	Pearson's r	p-value
Flat keratometric value, K1 (D)	0.139	0.251
Steep keratometric value, K2 (D)	0.491	<0.001
Maximum keratometric value, Kmax (D)	0.483	<0.001
Thinnest corneal thickness, TCT (μm)	−0.312	0.009
Central corneal thickness, CCT (μm)	−0.355	0.003
Posterior elevation (μm)	0.260	0.029

4.3.2 Graph 3



Correlation between corneal astigmatism and Kmax.

CHAPTER FIVE DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

The present study evaluated the correlation between corneal astigmatism and corneal topographic indices in eyes with different keratoconus statuses. The results showed that keratoconus-suspect eyes were the largest group, followed by keratoconus-present and no-keratoconus eyes. This indicates that a considerable proportion of the studied eyes with astigmatism showed tomographic changes suggestive of keratoconus. These findings support the importance of corneal tomography in patients with significant astigmatism. Sidky et al. (2020) studied children with astigmatic error ≥ 2 D using the Sirius Scheimpflug tomographer and found keratoconus in 4.8% and keratoconus suspects in 4.4% of their study population. (21) They concluded that tomography screening is important in children with significant astigmatism.

The proportion of keratoconus and suspects in the present study was higher than that reported by Sidky et al. This difference may be related to differences in sample size, study population, selection of participants, and classification criteria. Therefore, the results should be interpreted within the characteristics of the present study population rather than being considered as a general population prevalence. (Table 1 and figure 1)

From table 2 significant differences were found among the three groups for K1, K2, Kmax, astigmatism, TCT, and CCT ($p < 0.05$). K1, K2, Kmax, and astigmatism were higher in the keratoconus-present group, while TCT and CCT were lower. Posterior elevation was higher in the keratoconus-present group, but the difference was not statistically significant ($p = 0.149$). These findings indicate that several topographic parameters differed according to keratoconus status particularly K2, Kmax, TCT and CCT

Figure 1 specifically showed that mean Kmax was highest in the keratoconus-present group, followed by the suspect group, and lowest in the no-keratoconus group. This indicates greater corneal steepening in eyes classified as keratoconus.

A significant positive correlation was found between corneal astigmatism and K2, indicating that higher astigmatism was associated with a steeper keratometric value. Similarly, Kmax showed a significant positive correlation with astigmatism. This suggests that eyes with higher astigmatism tended to have greater maximum corneal curvature (Table 3). The scatter plot also demonstrates this positive relationship between astigmatism and Kmax. (Figure 3)

These findings are consistent with Ibrahim et al. (2021), who studied Egyptian subjects with high corneal astigmatism using Pentacam Scheimpflug imaging and found a significant relationship between astigmatism and Kmax. This supports the importance of Kmax as an important topographic parameter when evaluating eyes with high astigmatism for possible keratoconus. (22)

In contrast, K1 did not show a significant correlation with corneal astigmatism in the present study. This suggests that the relationship with astigmatism was more evident for the steep and maximum corneal curvature measurements than for the flat keratometric value.

A significant negative correlation was found between corneal astigmatism and TCT and CCT. This means that higher astigmatism was associated with lower corneal thickness measurements. This finding is important because corneal thinning is one of the structural changes associated with keratoconus. The present finding is also consistent with the tomographic changes reported in previous keratoconus studies.

A significant positive correlation was also found between astigmatism and posterior elevation. However, posterior elevation did not show a statistically significant difference among the three keratoconus-status groups. Therefore, although posterior elevation was associated with astigmatism, it may be less useful as an individual parameter for distinguishing the three groups in the present study.

Overall, the findings indicate that corneal astigmatism is associated with several important tomographic changes, particularly increased K2 and Kmax and reduced TCT and CCT. These findings support the use of corneal topography for identifying eyes that may require further evaluation for early keratoconus.

5.2 CONCLUSION:

- The present study found:
- A considerable proportion of keratoconus-suspect and keratoconus-present eyes among the studied eyes with astigmatism.
- Keratoconus-present eyes showed higher corneal curvature parameters and lower corneal thickness measurements.
- Corneal astigmatism was significantly associated with K2, Kmax, TCT, CCT and posterior elevation, while its correlation with K1 was not significant which mean k1 does not predict early keratoconus.
- These findings suggest that significant corneal astigmatism may be associated with changes in corneal topographic indices related to keratoconus
- And corneal topography with pentacam can be useful for early identification of suspicious cases.

5.3 LIMITATIONS:

The study was limited by its cross-sectional design and relatively limited sample size, which may cause findings relatively less generalized. As corneal parameters were assessed at a single time point, the progression of early keratoconus could not be evaluated. The study was also focused on selected corneal topographic and tomographic parameters, while other potentially useful diagnostic and biomechanical indices were not included in the study.

5.4 Recommendation:

Further studies with larger sample sizes and longer follow-up periods and additional diagnostic parameters are specifically recommended to confirm the relationship between corneal astigmatism and early keratoconus indication hopefully they may provide a more comprehensive assessment to indicate early keratoconus. Corneal topography along with pentacam and pachymetry should be considered in the patients with significant astigmatism, especially when other clinical or other ocular findings suggest possible keratoconus.

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