A Dissertation on

"COMPARISON AND ANALYSIS OF SYMMETRY INDEX BACK IN SUBCLINICAL AND CLINICAL KERATOCONUS USING SCHEIMPFLUG IMAGING"

Submitted in partial fulfilment of requirements of

M.S. OPHTHALMOLOGY

BRANCH – III

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MADRAS MEDICAL COLLEGE

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Submitted to

THE TAMIL NADU DR.M.G.R. MEDICAL UNIVERSITY, CHENNAI

May - 2022

CERTIFICATE

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I here declare this dissertation entitled "**COMPARISON AND ANALYSIS OF SYMMETRY INDEX BACK IN SUBCLINICAL AND CLINICAL KERATOCONUS USING SCHEIMPFLUG IMAGING"** is a bonafide and genuine research work carried out by us under the guidance of, Department of cornea , Regional Institute of Ophthalmology and Government Ophthalmic Hospital, Egmore, Chennai-08. And we also assure that this research project was not copied or borrowed from any other research projects.

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Dear Dr. R.B.SHAZIAA,

The Institutional Ethics Committee has considered your request and approved your study titled **"COMPARISION AND ANALYSIS OF SYMMETRY INDEX BACK IN SUBCLINICAL AND CLINICAL KERATOCONUS USING SCHEIMPFLUG IMAGING"- NO.42122020.** The following members of Ethics Committee were present in the meeting held on **15.12.2020** conducted at Madras Medical College, Chennai 3.

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CERTIFICATE –II

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CONTENTS

INTRODUCTION

Keratoconus Greek work (kerato:cornea; konos:cone),meaning cone-shaped protrusion of the cornea with focal thinning. It is a bilateral and asymmetric condition characterized by a progressive evolution. Keratoconus is a non-inflammatory disorder due to lack of neovascularization and cellular infiltration. This leads to increasingly irregular astigmatism as well as a steeper corneal curvature. This causes image blur and poor visual acuity. A strong association is found between eye rubbing and the development of keratoconus. Inferior steepening, superior flattening, skewed radial axes, decentered corneal thinning, islands of anterior and posterior elevation are all corneal topographic and tomographic findings consistent with keratoconus. In 1748, German oculist Burchard Mauchart provided an early description of a case of keratoconus, which he called staphyloma diaphanum.The prevalence of keratoconus is 54.5 per 1 lakh population.

EPIDEMIOLOGY

The prevalence reported ranges from 50 to 230 per 100,000. Keratoconus affects all races and both sexes equally with an onset around puberty(2)

GENETICS

Six genes have been found to be associated with keratoconus. These genes include BANP-ZNF469, COL4A4, FOXO1, FNDC3B, IMMP2L and RXRA-COL5A1 Mapping studies have identified a number of loci for autosomal-dominant inherited keratoconus.

ANATOMY OF CORNEA

The cornea is an avascular tissue which provides most of the refractive power of the eye . It comprises of five layers: The stratified epithelium & basement membrane, Bowman's layer, stroma, descemet's membrane and endothelium. The corneal epithelium is 50 microns thick approximately and comprises of 4-6 layers of non-keratinized stratified squamous epithelial cells. Its basement membrane is composed mainly of collagen type IV, laminin and entactin; and the major proteoglycan is perlecan . Bowman's layer separates the epithelial basement membrane from the stroma. Its thickness is about 8-12 microns and collagen fibrils interweave into the stroma . The stroma comprises the bulk of the cornea which is 500 microns thickness approximately and it has a highly ordered network of collagen fibrils and extracellular matrix. Type I collagen is most common out the other collagens. The major stromal proteoglycans are biglycan, lumican, keratocan and osteoglycin

EMBRYOLOGY

At five to six weeks of gestation the surface ectoderm separates out from the lens vesicle and forms the epithelium which is of one to two cell layers thickness. There is a loose acellular layer which becomes the stroma. By the end of six weeks, junctional complexes appears between the cells. On the seventh week , mesenchymal cells derived from the neural crest ,they migrate forward from the lens vesicle in three waves:

a. The **first wave** of cells migrates between the surface ectoderm and lens and forms the corneal endothelium and trabecular endothelium.

b. The **second wave** migrates between the corneal epithelium and endothelium and forms the corneal stroma.

c. The **third wave** migrates between the corneal endothelium and lens and forms the iris stroma.

The final adult epithelium is attained within 37 weeks.

DIMENSIONS

The anterior corneal surface is elliptical with an average horizontal diameter of 11.7 mm and vertical diameter of 11 mm.

The posterior corneal surface is circular with an average diameter of 11.5 mm. Thickness of cornea in the centre is about 0.52 mm while at the periphery it is 0.7mm. Radius of curvature in the central 5 mm area of the cornea forms the powerful refracting surface of the eye. The anterior and posterior radii of curvature of this central part of cornea are 7.8 mm and 6.5 mm, respectively. Refractive corneal power is about 45 dioptres, which is three-fourth of the total refractive power of the eye (60 dioptres).

HISTOLOGY

Histologically, the cornea consists of five distinct layers. From anterior to posterior these are: epithelium, Bowman's membrane, substantia propria (corneal stroma), Descemet's membrane and endothelium

1. **Epithelium**: It is stratified squamous and becomes continuous with the epithelium of bulbar conjunctiva at the limbus. It consists of 5-6 layers of cells. The basal layer comprises of columnar cells, next 2-3 layers of wing or umbrella cells and the most superficial two layers are of flattened cells.

2. **Bowman's membrane**: This layer consists of the acellular mass of condensed collagen fibrils. Its thickness is about 12µm and it binds the corneal stroma anteriorly with basement membrane of the epithelium. It is not a true elastic membrane but a condensed superficial part of the stroma. It shows considerable resistance to infection. It does not regenerate once destroyed

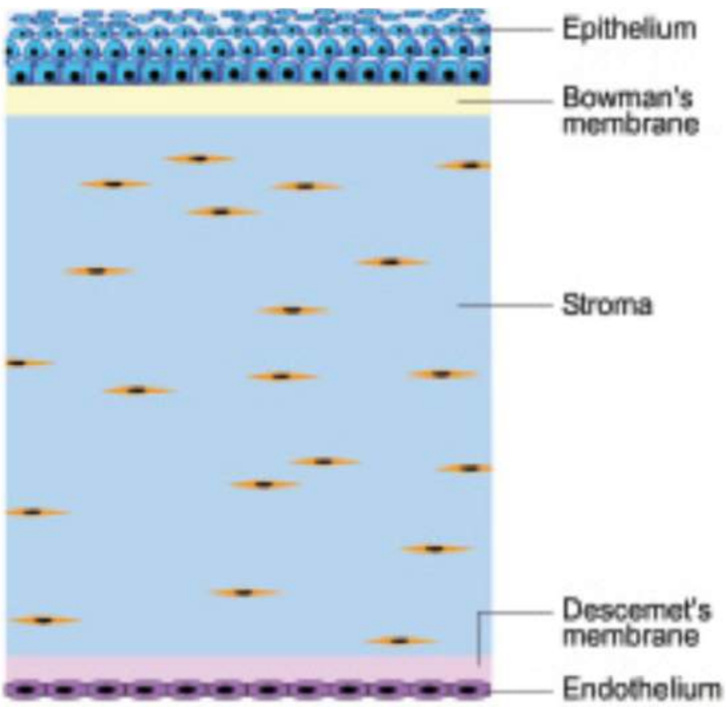
3. **Stroma (substantia propria)**: This layer is about 0.5 mm in thickness and constitutes most of the cornea (90% of total thickness). It consists of collagen fibrils (lamellae) embedded in hydrated matrix of proteoglycans. The lamellae are arranged in many layers. In each layer they are parallel to each other and also to the corneal plane and become continuous with scleral lamellae at the limbus. The alternating layers of lamellae are at right angle to each other. keratocytes, wandering macrophages, histiocytes and leucocytes are present among the lamellae.

4.**Pre-Descemet Layer, or Dua Layer:** It is recently identified by Dua et al as it showed few differences from normal corneal stroma. It measured about 10.15 ± 3.6 µm thick .It consists of five to eight thin lamellae of tightly packed collagen bundles. Collagen types IV and VI seemed to be more positive for PDL compared with the corneal stroma.

5. **Descemet's membrane** (posterior elastic lamina): It is a strong homogenous layer which binds to the stroma posteriorly. It is resistant to chemical agents, trauma and pathological processes. 'Descemetocele' helps in maintaining the

integrity of eyeball for long. Descemet's membrane consists of collagen and glycoproteins. Unlike Bowman's membrane it can regenerate. Normally it remains in a state of tension and it curls inwards on itself when it is torn . In the periphery it appears to end at the anterior limit of trabecular meshwork as Schwalbe's line (ring).

5. **Endothelium:** It comprises of a single layer of flat polygonal cells which appear as a mosaic on slit lamp biomicroscopy . The cell density of endothelium is around 3000 cells/mm2 in young adults , it decreases as age advances . There is a considerable functional reserve for endothelium. More than 75 percent of cell loss causes corneal decompensation. The endothelial cells contain 'active-pump' mechanism.



INNERVATION OF THE CORNEA

The nerve fiber bundles in the sub-basal plexus of the human cornea they form regular dense meshwork with equal density over a large central and peripheral area. The thin sensory nerves, derived from the first and second division of the trigeminal nerve run parallel to the Bowman's layer in the subepithelial plexus. 18 A-delta-fibers run straight and parallel to the Bowman's layer beneath the basal epithelial plexus while the C-fibers, run parallel to the Bowman's layer, send multiple branches penetrating epithelial cell layers and ends blindly in the superficial cells.There are about 6000 nerve bundles in the human sub-basal plexus each of which gives upto seven axons resulting in about 19000 to 44000 axons. These in turn gives off 10 to 20 nerve terminals which result in roughly 7000 nociceptors/mm2 and it makes the cornea a highly innervated structure in the body. The sub-basal nerve plexus comprises of unmyelinated sub-basal nerve fiber bundles which are straight and beaded fibers, that course in the basal aspect of the basal epithelial cell layer and are easily seen in confocal microscopy imaging. The function of these nerves, along with a few sympathetic nerves which also supply the cornea is critical to the health of various corneal tissue. Within 12 to 24 hour of corneal nerve impairment or loss, the epithelial cells swell and lose their micro-villi, and begin to slough at an accelerated rate. Denervated cornea impairs the ability of the epithelium to heal after injury and newly healed tissue is at the high-risk of spontaneous breakdown. A complication of denervation is dry eye. On unilateral dysfunction of the first division of the

trigeminal nerve, reduced aqueous tear production occurs.

VASCULAR SUPPLY OF THE LIMBUS

The anterior ciliary artery is a branch of the ophthalmic artery which anastomoses with vessels derived from the facial branch of the external carotid to form a vascular arcade around the limbus.

APPLIED PHYSIOLOGY

The two primary physiological functions of the cornea are

(i) To act as a major refracting medium; and

(ii) To protect intraocular contents.

CORNEAL TRANSPARENCY

The transparency is the result of :

- Peculiar arrangement of corneal lamellae (lattice theory of Maurice),
- Avascularity

- Relative state of dehydration maintained by barrier effects of epithelium and endothelium and the active bicarbonate pump of endothelium.

SOURCE OF NUTRIENTS

1. Solutes (glucose and others) enter the cornea by simple diffusion or active transport through aqueous humour and by diffusion from the perilimbal capillaries.

2. Oxygen is derived directly from air through the tear film which is an active process by the epithelium.

METABOLISM OF CORNEA

The most actively metabolising layers of the cornea are epithelium and endothelium, the former being times thicker than the latter requires a proportionately larger supply of metabolic substrates. Like other tissues, the epithelium can metabolize glucose both aerobically and anaerobically into carbon dioxide and water and lactic acid, respectively. Thus, under anaerobic conditions lactic acid accumulates in the cornea.

KERATOCONUS

ETIOLOGY

It is unknown and mostly multifactorial. There is a strong association between eye rubbing and the development of keratoconus is due to the activation of wound healing processes and signalling pathways secondary to mechanical epithelial trauma and also direct rubbing-related mechanical trauma to the keratocytes and increased hydrostatic pressure in the eye. Contact lens wear is another form of corneal microtrauma associated with keratoconus. The hereditary pattern is not predictable although the strongest evidence of genetic involvement is a high concordance rate in monozygotic twins. A positive family history has been reported in 6-8% of the cases.

PATHOLOGY

Keratoconus can involve each layer of the cornea. The corneal epithelial cells may be enlarged and elongated. Early degeneration of basal epithelial cells can be followed by disruption of the basement membrane. This disruption results in the growth of epithelium posterior to the Bowman's layer and collagen anterior to the epithelium, forming typical Z-shaped interruptions or breaks in the Bowman's layer. Scarring of the Bowman's layer and the anterior stroma are common and present histopathologically with collagen fragmentation, fibrillation and fibroblastic activity. The stroma has normal-sized collagen fibers but low numbers of collagen lamellae, which results in stromal thinning. Endothelial cell pleomorphism and polymegathism may also be manifested. With increasing severity and duration increase, greater change and damage occurs at the base of the cone than at the apex

HISTOLOGIC FINDINGS

All layers of the cornea are affected by keratoconus. It is characterized by severe corneal stromal thinning and focal deficits in epithelium and Bowman's layer, the latter being the earliest of the abnormalities. Superficial epithelial cells located at the apex of cone are elongated and arranged in a whorl-like fashion. There is a decrease in the number of stromal collagen lamellae and also a loss of the fibular arrangement within the lamellae. Iron deposition in the basal corneal epithelial cells forms the characteristic Fleischer ring. Ruptures in Descemet's membrane are associated with influx of fluid into corneal stroma in acute hydrops. The endothelium is usually normal.

PATHWAYS INVOLVED IN KC

CYTOKINE DYSREGULATION

IL-17 over-expression in pooled samples from KC patients. The corneal epithelium is one of the targets of IL-17 and when human corneal epithelial cells lines are exposed to stress they can produce cytokines that promote

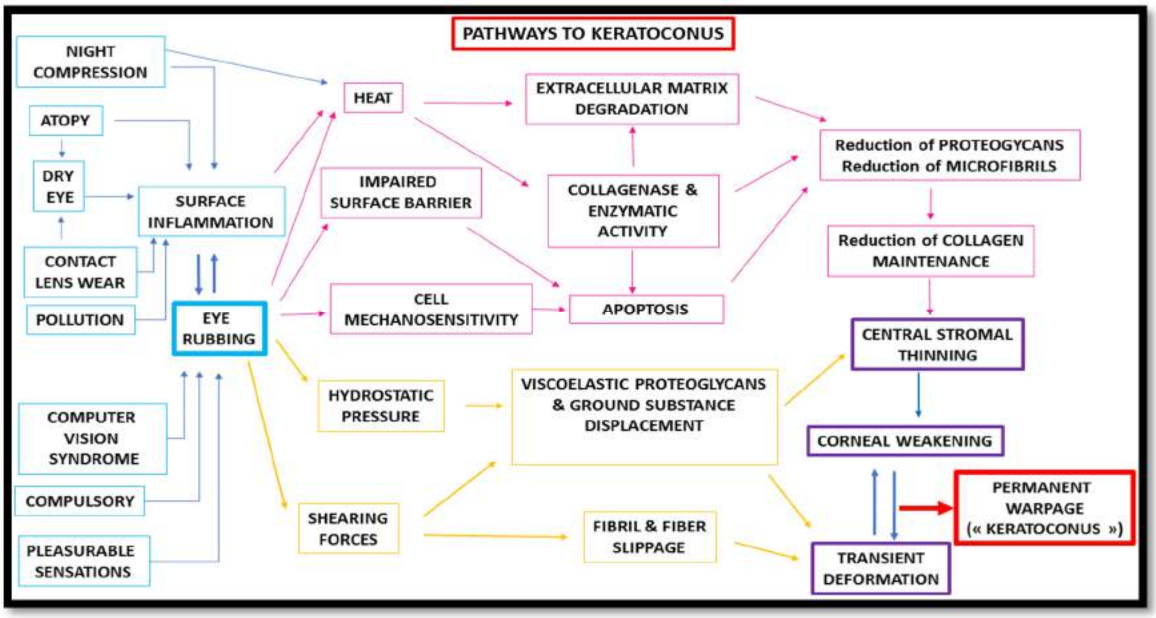
Th-17 differentiation.

OXIDATIVE STRESS

Catalase is the major pathway through which the cells dispose of excess hydrogen peroxide. upregulations of numerous types of cathepsins, which by themselves can promote hydrogen peroxide formation, thereby feeding the oxidative cycle. This overall pro-oxidative environment was hypothesized to trigger the tissue destruction seen in KC.

ALTERATIONS IN TGF-B AND THE EFFECT ON THE EXTRACELLULAR MATRIX (ECM)

human corneal stromal fibroblasts exposed to various isoforms of TGF-β demonstrated a differential fibrotic response, especially in cells exposed to TGF-β3, an isoform known for its anti-fibrosis properties



THEORIES OF KERATOCONUS

– Isolated sporadic

– Heredity

– Association with systemic conditions

– Eye rubbing

– Hormonal change

- Rigid contact lens wear.

ASSOCIATIONS OF KERATOCONUS

• **SYSTEMIC DISORDERS:**

– Down syndrome, Turner syndrome

– Ehlers-Danlos and Marfan syndromes, osteogenesis imperfecta, mitral valve prolapse

– Atopic dermatitis

– Bardet-Biedl syndrome, Crouzon's syndrome, Laurence-Moon-Biedl syndrome, Goltz-Gorlin syndrome, Nail-patella syndrome.

• **OCULAR DISORDERS:**

– Vernal keratoconjunctivitis

– Leber's congenital amaurosis

– Retinitis pigmentosa

– Blue sclera, aniridia, ectopia lentis.

significant risk factors include history of atopy, contact lens wear and constant eye rubbing.

CLINICAL FEATURES

SYMPTOMS

- Deteriorating visual acuity, distortions, glare
- Frequent changes in refraction
- Visual acuity not refractable to 6/6
- Monocular polyopia or ghosting

SIGNS

EXTERNAL SIGNS

- **MUNSON'S SIGN**: It is the indentation of lower lid caused by the protruding apex of the cornea. It is seen in advanced cases of keratoconus.

• **RIZUTTI'S SIGN**: A light reflex projected from the temporal side will be displaced beyond the nasal limbal sulcus when high astigmatism and steep curvatures are present.

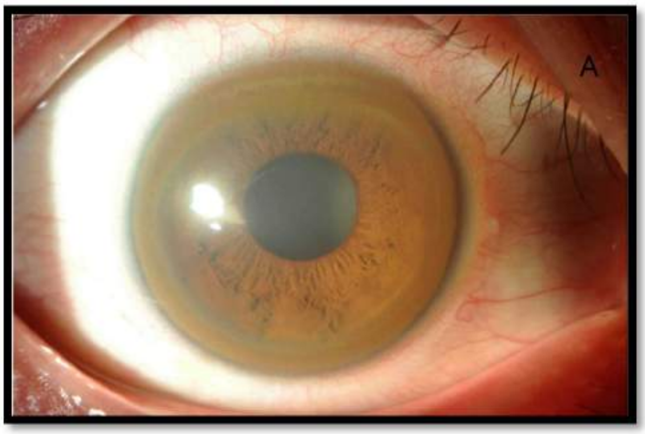
SLIT LAMP SIGNS

• **VOGT'S STRIAE**:

It is the earliest slit lamp finding noted in moderate which are fine stress lines in the deep stroma.

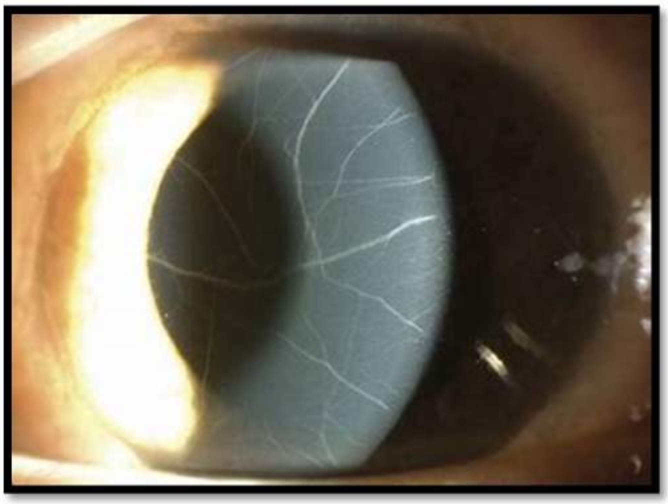
• **FLEISCHER RING**:

It is seen in moderate keratoconus as the deposition of iron in the basal epithelial cells in a ring shape at the base of the conical protrusion. It is seen better in cobalt blue filter.



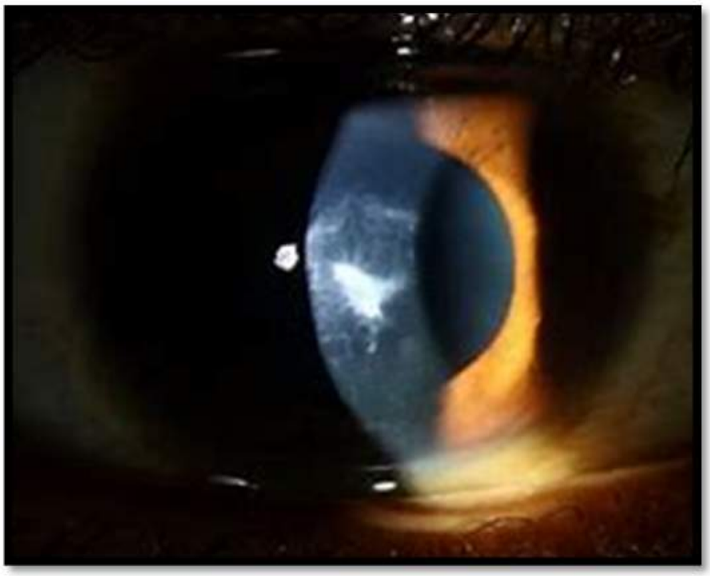
• **PROMINENT CORNEAL NERVES**:

They are nerve fibers which are more easily seen due to density changes.



• **CORNEAL APICAL SCARRING**:

It appears at the apex of the cone which starts as fine lines and then develop into nebular scarring which can progress further. It is worsened by the wearing of rigid contact lenses



• **HYDROPS**:

It is the acute rupture in Descemet's membrane causing development of sudden onset redness and pain due to imbibition of aqueous into corneal stroma causing it to swell.

RETROILLUMINATION SIGNS

• **Scissoring reflex on retinoscopy**:

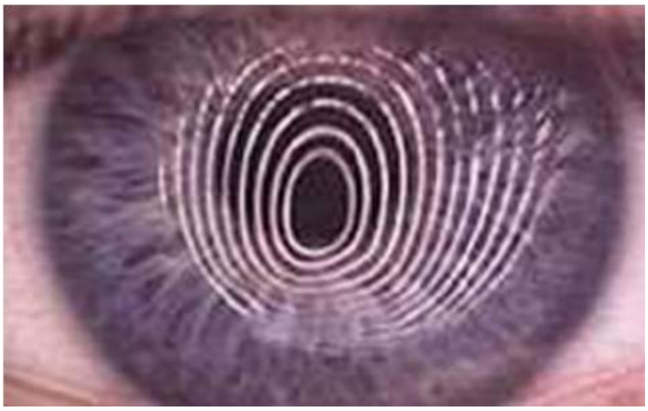
The reflex appears to spin or swirl around a point corresponding to the apex of the cone.

•**Oil droplet sign** ("Charleaux" sign): This sign is noticed on distant direct ophthalmoscopy.

PHOTOKERATOSCOPIC SIGNS

• Compression of mires infero-temporally or centrally

• "Egg shaped mires"



VIDEOKERATOGRAPHY SIGNS

• Localized increase of surface power which is usually present in the inferior or inferotemporal cornea

• Inferior superior diopteric asymmetry.

• Relative skewing of steepest radial axes above and below the horizontal meridian (SRAX pattern).

CLASSIFICATION OF KERATOCONUS

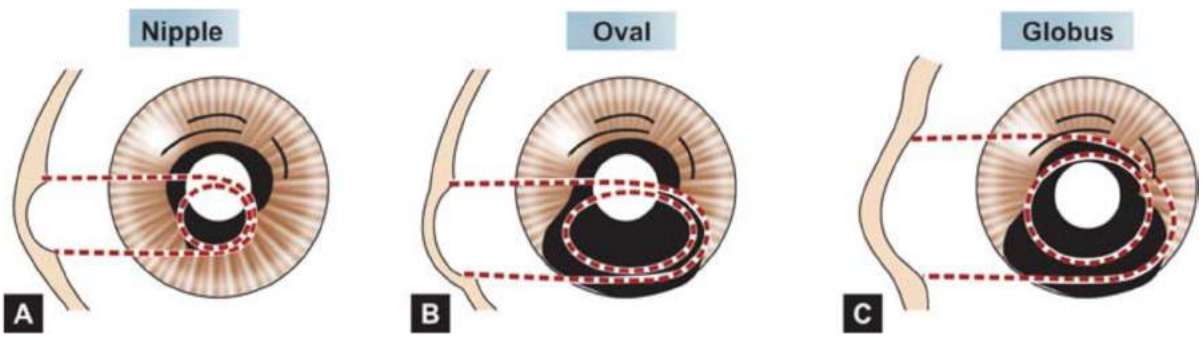
• Based on Cone type

– **Nipple cone** is a small, near central cone, less than 5.0 mm in diameter.

– **Oval cone** is the most common type of cone found in advanced keratoconus.

Apex of cone is displaced well below the midline resulting in varying degrees of inferior mid-peripheral steepening.

– **Globus cone** is a large cone often affecting nearly three quarters of the corneal surface, more than 6.0 mm in diameter.



• **Corneal curvature (keratometry)**

The classification of keratoconus based on keratometry values is follows:

– Mild <48D

– Moderate 48 to 54 D

– Severe >54D

• Slit lamp findings, retinoscopy and corneal topography

RABINOWITZ CLASSIFICATION:

It is based on topographic progression of keratoconus -suspect and early keratoconus to clinically significant keratoconus.

• **Keratoconus**: Corneal thinning by slit lamp examination accompanied by one or more of the following clinical signs—Vogt’s striae, Fleischer’s ring, Munson sign, scissoring of the retinoscopic reflex an asymmetric bow tie with skewed radial axes in videokeratography pattern (AB/ SRAX).

• **Early keratoconus**: No slit-lamp findings but scissoring of the retinoscopic reflex with fully dilated pupil examination with an AB/SRAX videokeratography pattern.

• **Keratoconus-suspect**: No clinical signs of keratoconus, no scissoring on retinoscopy but an AB/SRAX videokeratography pattern.

• **Normal**: No clinical signs of keratoconus, no scissoring on retinoscopy, no AB/SRAX pattern on videokeratography

AMSLER–KRUMEICH CLASSIFICATION

It based on the analysis of corneal topography, corneal thickness, refraction and biomicroscopy

STAGE	CHARACTERISTICS
I	Eccentric corneal steepening Induced myopia /astigmatism<5D Corneal radii≤48D Vogt's striae, no scars
II	Induced myopia and/or astigmatism>5D, < 8 D Corneal radii ≤53D No central scars Corneal thickness ≥400 µm
III	Induced myopia and/or astigmatism>8D, <10D Corneal radii>53D No central scars Corneal thickness200—400 µm
IV	Refraction not measurable Corneal radii >55D Central scars, perforation Corneal thickness<200 µm

THE RABINOWITZ DIAGNOSTIC CRITERIA

It consist of three corneal topography derived indices, which, when abnormal, should alert the clinician to consider a diagnosis of keratoconus. These indices are as follows:

• **Keratometry value** quantifies the central steepening of the cornea that occurs in keratoconus. A value of 47.20 D or greater is suggestive of keratoconus.

• **I-S value** quantifies the inferior versus superior corneal dioptric asymmetry that occurs in keratoconus. A value of 1.4 D or greater is suggestive of keratoconus.

• **KISA percent** incorporates the K and I-S values with a measure, quantifying the regular and irregular astigmatism into one index.

KISA percent = K × I-S asymmetry × AST (degree of regular corneal astigmatism) × SRAX × 100

This index is highly sensitive and specific in differentiating the normal from keratoconic corneas. A value of greater than 100 percent is highly suggestive of frank keratoconus, and the range from 60 to 100 percent represents keratoconus suspects.

DIAGNOSTIC EVALUATION

Diagnosis of Keratoconus is done by refraction, slit lamp biomicroscopy, keratometry , Pachymetry and corneal topography**.**

KERATOMETRY

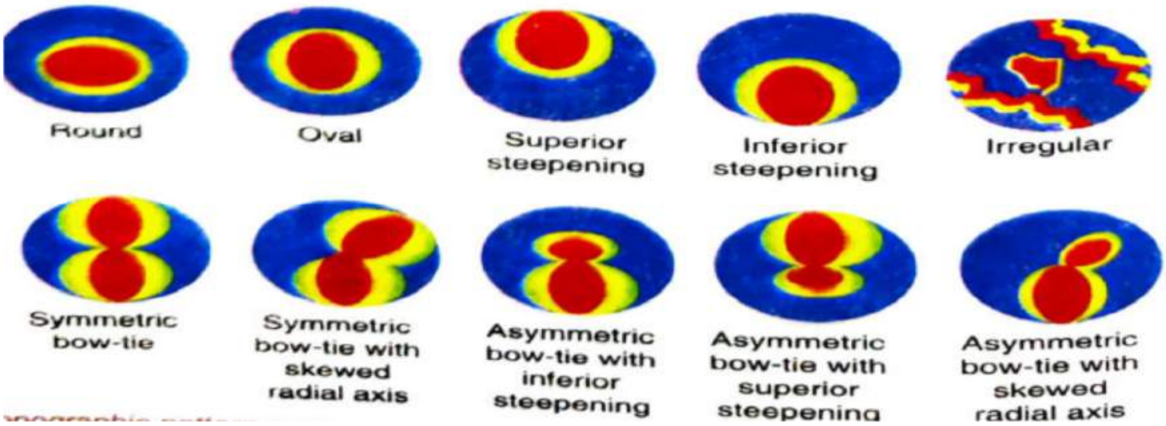
It measures the radius of curvature of the anterior corneal surface from four points approximately 3 mm apart. However, its limitations are that the corneal apex and peripheral cornea are not taken into account, it assumes corneal symmetry, measures a variable area and is less accurate in very steep and very flat corneas, and treats the cornea as a spherocylindrical structure with two principal meridia separated by 90 degrees, resulting in errors in astigmatic axis measurement.

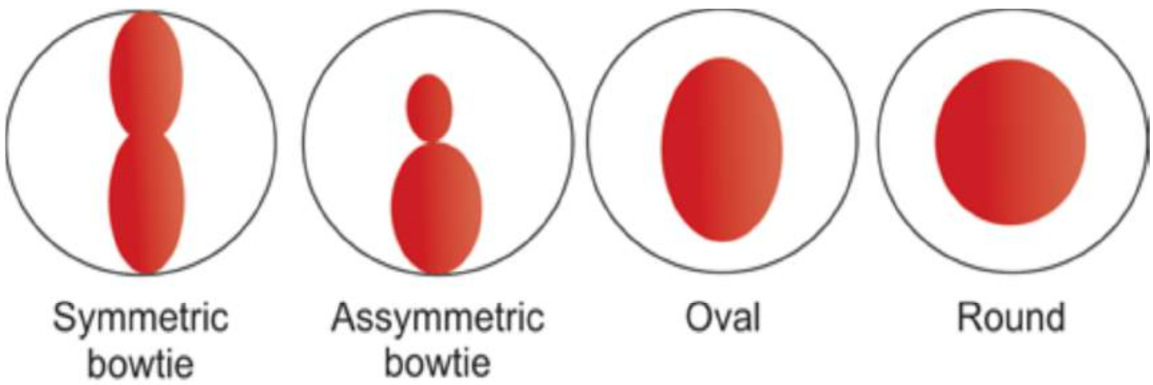
CORNEAL TOPOGRAPHY

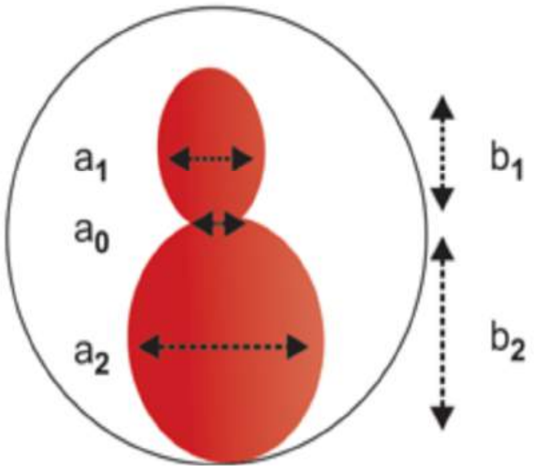
It uses three of the following principles

- Placido disc reflection
- Scanning slit
- Scheimpflug photography

10 different topographical patterns have been described by Rabinowitz et al.







Normal corneal topography patterns based on computer assisted videokeratography

Corneal topographic profiles might be categorized into three profiles, viz prolate, oblate or mixed. The normal cornea is prolate, with the center being the steepest and gradually flattening towards the periphery. Topographic patterns of the normal corneas can be described astigmatic patterns of the cornea in accordance to its pattern characteristics:

• **Round pattern**: The ratio of the shortest to the longest diameter at the color zone is 2/3 or more.

• **Oval pattern**: The ratio of the shortest to the longest diameter at the color zone is less than 2/3.

• **Regular astigmatism pattern**: This is seen when the two principal meridians are oriented at approximately right angles to each other. The angle between the axis of the two halves of the bowtie of less than 20degree is defined as regular astigmatism.

– **Symmetrical bowtie**

i. A central constriction is identified in the color zone

ii. The ratio a0 / a1 or a0 / a 2 is 1/3 or less

iii. The ratio of a1 / a2 or b1 / b 2 is 2/3 or more.

– **Asymmetrical bowtie**

i. A central constriction is identified in the color zone

ii. The ratio a0 / a1 or a0 / a 2 is 1/3 or less

iii. The ratio of a1 / a2 or b1 / b 2 is less than 2/3.

Irregular astigmatic pattern:

This pattern is defined when the angle between the two steepest semimeridia is greater than 20 degree and would represent a bi-oblique bowtie pattern or

when no pattern is discernible. Astigmatic corneas show bowtie appearances with the red bows lying along the steep meridian. In oblate corneas (as those undergone flattening by surgery), the bows are blue and lie along the flat meridian. Based on the various pattern descriptions, combination patterns of regular astigmatism such as prolate symmetric bowtie, prolate asymmetric bowtie, oblate symmetric bowtie, oblate asymmetric bowtie and irregular astigmatism such as prolate irregular, oblate irregular, mixed patterns and others such as steep/flat pattern, localized steepness pattern, triple pattern, horseshoe pattern.

Common **indications for corneal topography** in practice:

• Refractive surgery patients

– Preoperative assessment

– Postoperative follow-up

– For augmentation procedures.

• **Diagnostic**

– Screening for ocular disease

– Corneal ectasia

– Contact lens-induced corneal warpage.

• Planning surgical incision (cataract, astigmatic keratotomy)

– Incision location, length, depth

• Contact lens fitting in irregular corneas

• Intraocular lens power calculation in special situations

• Management of astigmatism

– Adjustment of incisions or sutures.

• Keratoplasty follow-up

• Others:

– Suture manipulation/removal

– Patient education

– Communication with colleagues

– Documentation for medicolegal purposes.

PLACIDO DISC REFLECTION FOR CURVATURE ANALYSIS

Placido disc is a device made of concentric rings drawn on a device of a different color (generally white rings on a black background).The first refracting surface of the acts as convex mirror and reflects back light in a pattern dependent of the corneal pattern

TOPOGRAPHIC DISPLAYS - PLACIDO BASED DEVICES

1. NUMERICAL POWER PLOTS: It shows the corneal curvature of specific areas is shown in dioptric values displayed in 10 concentric circular zones with 1mm interval between each.

2. KERATOMETRIC VIEW:It shows the keratometric reading at 2 principal meridian and 3 zones - at 3mm,3-5mm,5-7mm

3. PHOTOKERATOMETRIC VIEW: It is a black and white photograph of the Placido rings. Its importance is to judge the reliability of the topography.Improper fixation, dryness, abnormal tear film, partial closure of the eye can give rise to distorted mires.

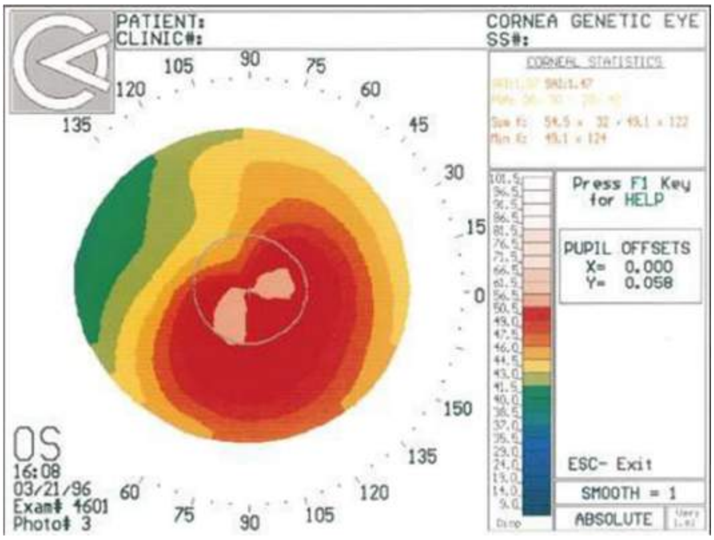
4. PROFILE VIEW:It is the graphical plotting along the X Y-axis of the steepest and flattest meridian of the cornea and the difference between the two in dioptres.

5. COLOR CODED TOPOGRAPHIC MAP

A. COLOUR CODES :

Hot colors (red and its shades) represent steep cornea

Cool colors (blue and its shades) represent flat corneas



B. SCALE USED

i) Absolute scale: It has colors representing 1.5D intervals between 35 and 50D and 5D intervals above and below them.

ii) Normalized scale: Here the cornea is divided into 11 equal colors spanning the eye’s total dioptric power Placido Disc Reflection for curvature analysis

C. INDICES

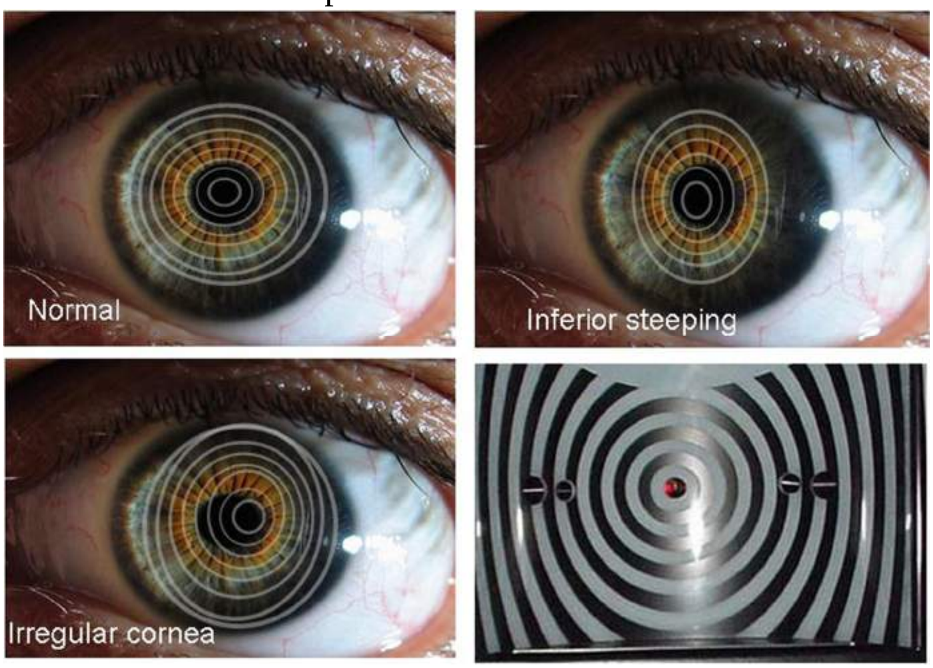
The key indices are:

i) SIMULATED KERATOMETRY (Sim K) : characterize corneal curvatures in the central 3-mm area. Sim K 1 is the greatest mean dioptric value and Sim K2 is calculated as the mean value of the meridian 90 to the previous.

ii) MINIMUM KERATOMETRIC VALUE (Min K) : lowest value along each meridian

iii) CYLINDER (Cyl) : The toricity of the surface obtained from the difference in the simulated keratometric value.

Placido disc is a device made of concentric rings drawn on a device of a different color (generally white rings on a black background).The first refracting surface of the acts as convex mirror and reflects back light in a pattern dependent of the corneal pattern



COMPUTER ASSISTED VIDEO KERATOSCOPY

It is the important diagnostic aid for very early as well as abortive forms of keratoconus in the other eye of the patients with unilateral keratoconus Data of videokeratoscopic image are analyzed by computers and depicted as color coded maps.

Red color indicates myopic refraction or ectasia

Blue color indicates hypermetropic refraction or flattening of the cornea.

Provides a color coded map of the corneal surface.

The power in diopters of the steepest and flattest meridians and their axes are calculated and displayed

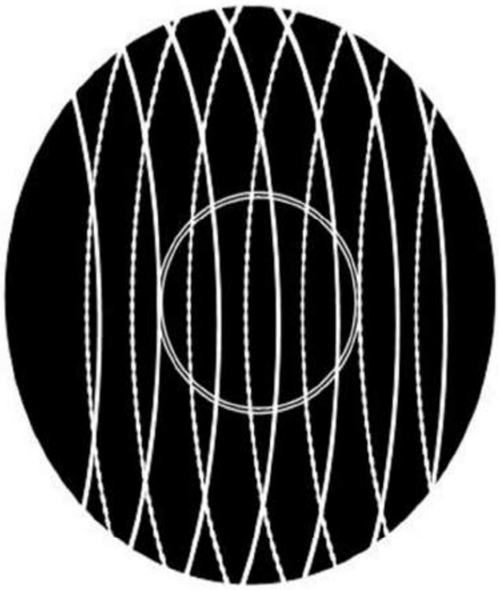
Steep curvatures are marked orange or red

Flat curvature in blue or violet

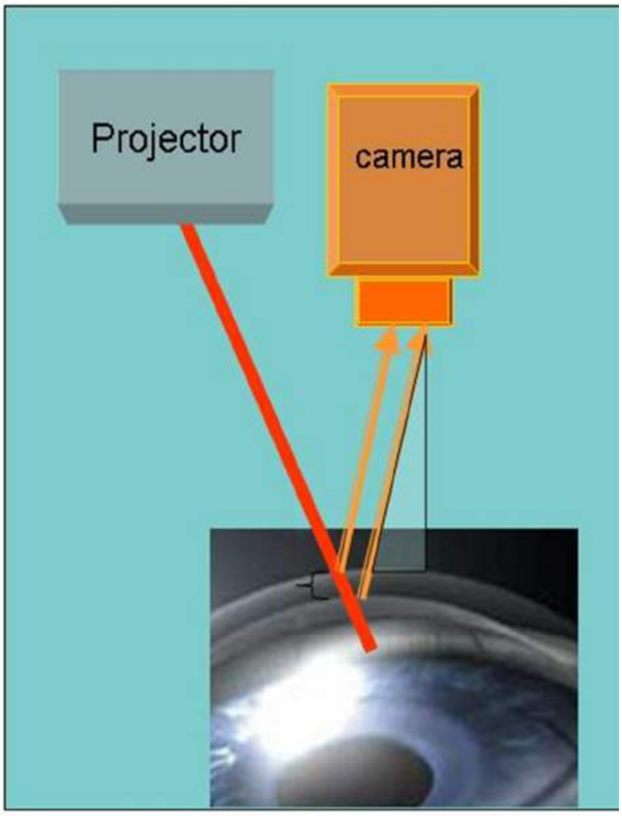
Normal curvatures in green or yellow

SCANNING SLIT ELEVATION EVALUATION

It is one of the elevation based methods for assessment of topography. Multiple complimentary slits are used to perform an assessment of the corneal surface. The triangulation between the reference slit beam surface and the reflected beam captured by the camera can be used to analyse the anterior and posterior corneal curvature and the pachymetry

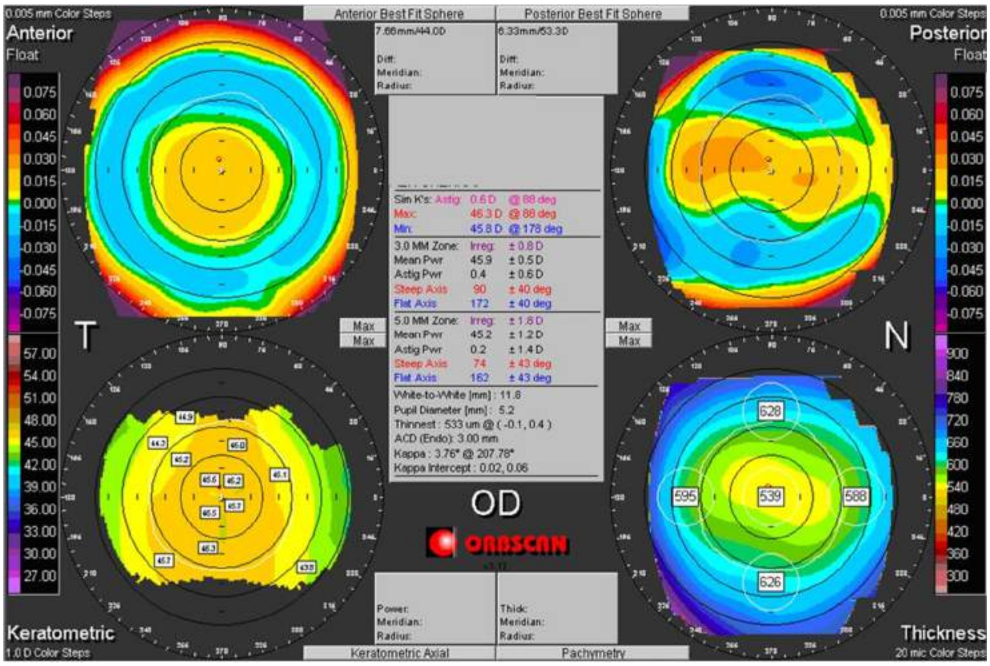


Scanning Slit pattern



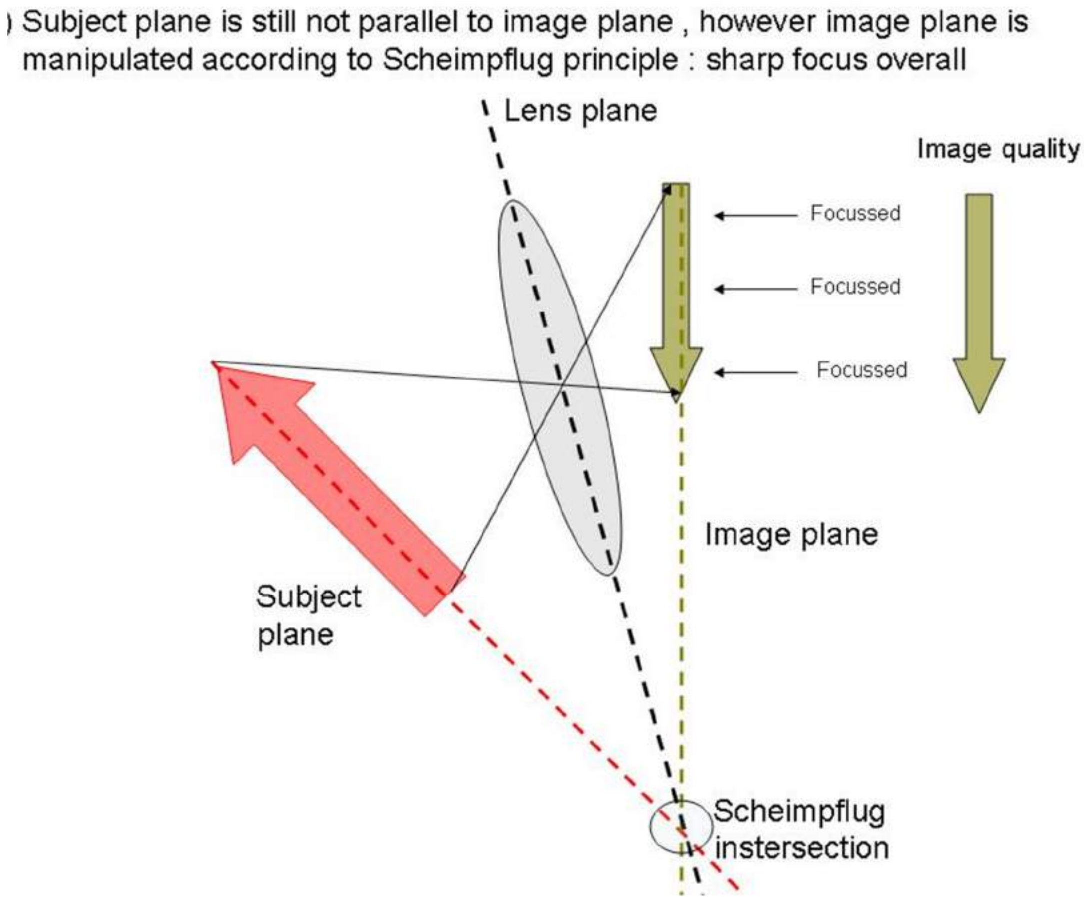
Concept of triangulation

In the Orbscan , 40 slits (20 each from nasal and temporal side) are projected on the cornea to assess 240 points on each slit



SCHEIMPFLUG PRINCIPLE BASED ASSESSMENT

In an ideal scenario , the lens plane and the image plane are parallel. Therefore a linear object will form a plane of focus parallel to the lens plane and thus can be focused totally on the image plane. But when the object is not parallel to the prospective image plane .It will not be possible to focus all the image on a plane parallel to image plane Thus this may lead to image distortion. However, according to the Scheimpflug principle, when a planar subject is not parallel to the image plane , an oblique tangent can be drawn from the image, object and lens planes, and the point of intersection is called schiempflug intersection



With a rotating Scheimpflug camera, the Pentacam can obtain 50 Scheimpflug images in less than 2 seconds. Each image has 500 true elevation points for a total of 25,000 true elevation points for the surface of the cornea. The Pentacam actually has 2 cameras. One is for the detection and measurement of pupil, which helps with orientation and fixation. The second camera is used for visualization of the anterior segment. The Pentacam is able to image the cornea such that it can visualize anterior and posterior surface topography, including curvature, tangential, and axial maps.

Advantages of the Pentacam include the following: (1) high resolution of the entire cornea, including the center of the cornea; (2) ability to measure corneas with severe irregularities, such as keratoconus, that may not be amenable to Placido imaging; and (3) ability to calculate pachymetry from limbus to limbus. The Pentacam can also provide corneal wavefront analysis to detect higher-order aberrations.

Problems with the Pentacam include eye movement during the 2 second measurement process, although this is unlikely to be a large amount. However, calculation of corneal power from elevation measurements has several limitations. Hence, the ultimate solution may be to use both a Placido based image analysis for corneal power requirements and to interpret these in light of data above corneal elevation from devices like the Pentacam – for both the anterior and posterior corneal surfaces. Although the instruments described are the prototype devices for the measurement principles propounded, and the ones most in use today, other devices exist.

TOPOGRAPHIC MAPS:

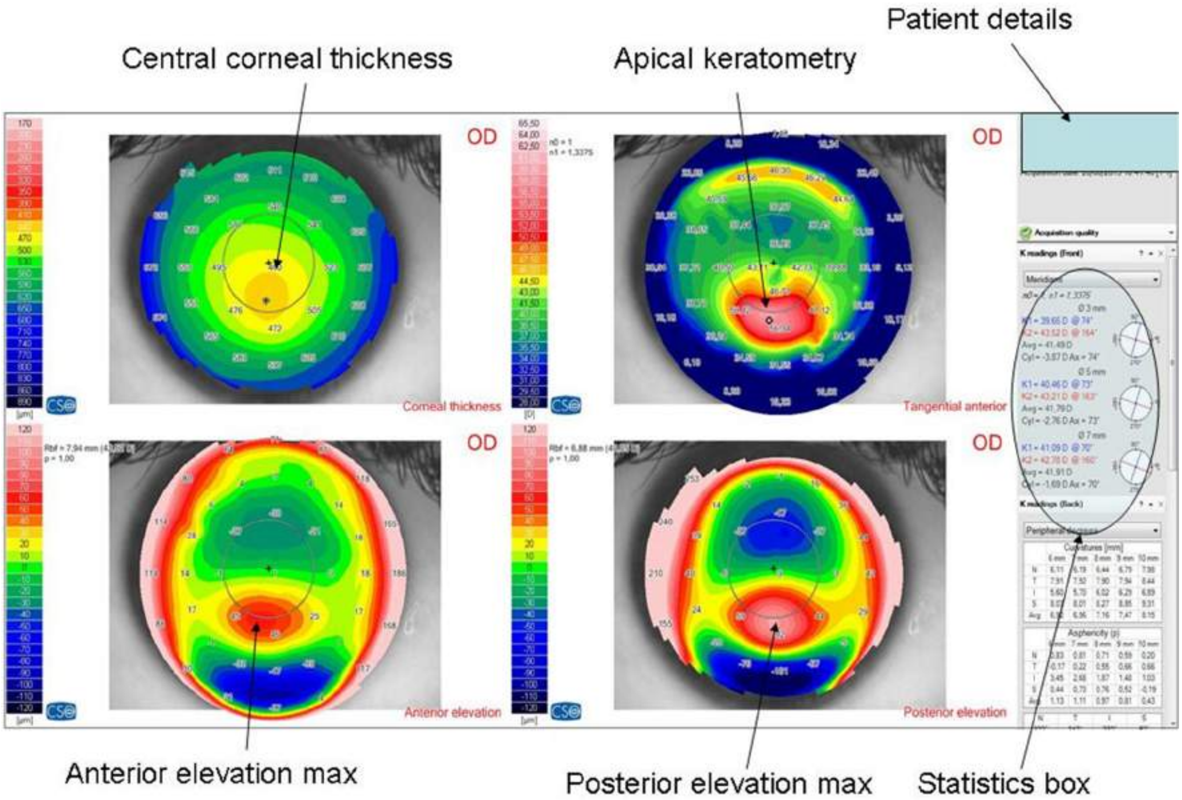
i) CORNEAL POWER MAP (AXIAL) :It represents the corneal power at various points on the cornea in dioptric values with the constraint that all the centres of rotation must fall on the axis defined by the optical axis of the VKC.

ii) TANGENTIAL MAP: Or the instantaneous curvature map gives a better geographical representation because each point on the curvature has an independent radius of curvature. It represents localised changes and peripheral data better than axial maps. It is the best indicator of corneal shape but a poor indicator of corneal power

iii) ELEVATION MAP: It helps to identify localized elevations. Warm colors represent elevated areas above the reference sphere and cooler colors represent depressed areas.

iv) REFRACTIVE MAP: Or the asphericity map takes into account spherical aberrations. It shows how the cornea refracts light. Aspherical cornea has cooler colors centrally and warm colors peripherally. It is useful to determine the optical zone of the RGP lens, and in performing refractive corneal surgery.

v) IRREGULARITY MAP: It displays the distortion of the cornea with reference to a previous elevation map i.e a best fit spherocylindrical toric surface as reference sphere. It enables quick diagnosis of any corneal abnormality causing visual disturbances.



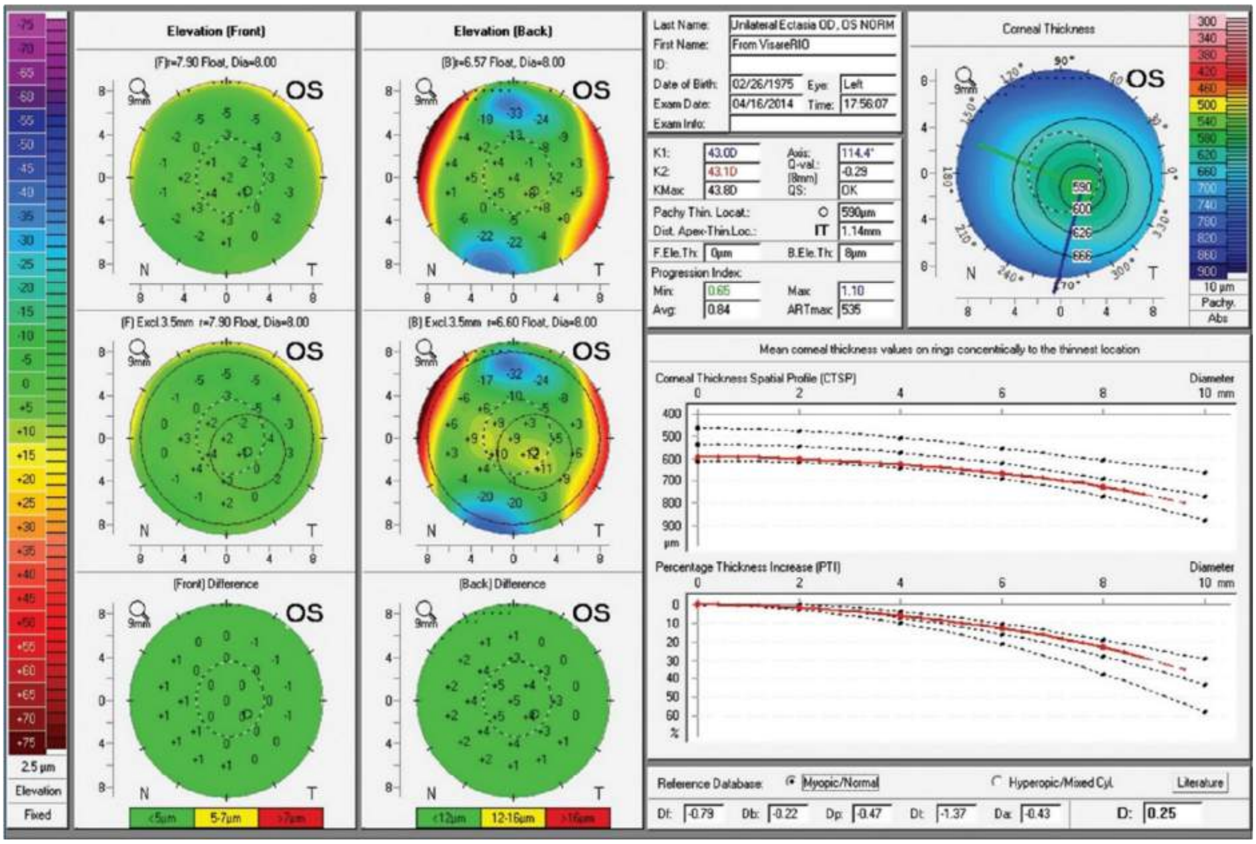
Example of Keratoconus as evidenced on a Pentacam Scheimpflug evaluation

Belin/ Ambrosio Ectasia Display

· Central 4 mm optical zone excluded and Enhanced best fit sphere is calculated

· Enhanced BFS resembles closely the normal peripheral cornea and exaggerates the conical protrusion or ectasia

· Ambrosio Relational thickness - (ART) = Thinnest point/Pachymetry



SCHEIMPFLUG BASED SIRIUS TOPOGRAPHER

INDICES

HIVD (Horizontal Iris Visible Diameter)

Horizontal diameter of the cornea, in millimeters.

Pupil (Topographic)

The center of the pupil is marked on the maps with the + cross

Thinnest Point

The thinnest point of the cornea is marked on the corneal thickness map with the symbol.This window reports the position of the thinnest point and the thickness at that point (Thk).

Apex

The corneal apex is marked by the × cross on the anterior tangential map. This window reports the position of the apex and the thickness at that point.

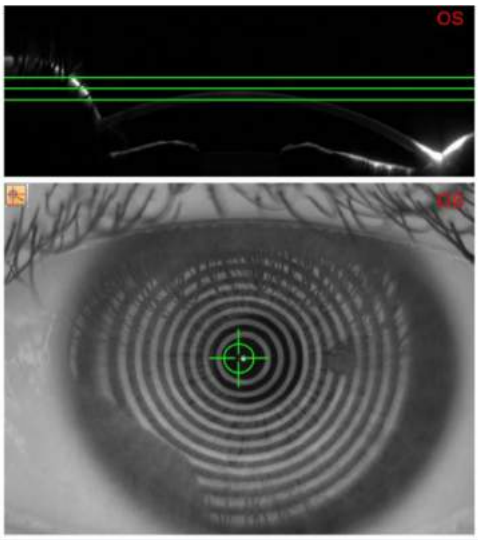
Anterior Chamber

The depth of the anterior chamber from the top of the cornea at the top of the lens. The total height of the anterior chamber corresponds to the thickness corneal CCT (central corneal thickness) + the anterior chamber depth (ACD Anterior Chamber Depth) in millimeters. It also indicates the volume of the anterior chamber in cubic millimeters.

HADC (Horizontal Anterior Chamber Diameter) is measured as the distance between the vertices of the iridocorneal angles.

Corneal Volume

Indicates the corneal volume within a diameter equal to 10 mm



KERATOMETRIES

Sim-K

The Sim K index simulates the readings that would be obtained with a keratometer, i.e. the mean sagittal curvature from the 4th to the 8th Placido ring.

K1: the flattest meridian (in blue) with its curvature (expressed in mm or D, depending on which option is selected from the Options/Curvatures menu), direction, and asphericity (expressed in p, e, Q, or SF, depending on which option is selected from the Options/Asphericity menu).

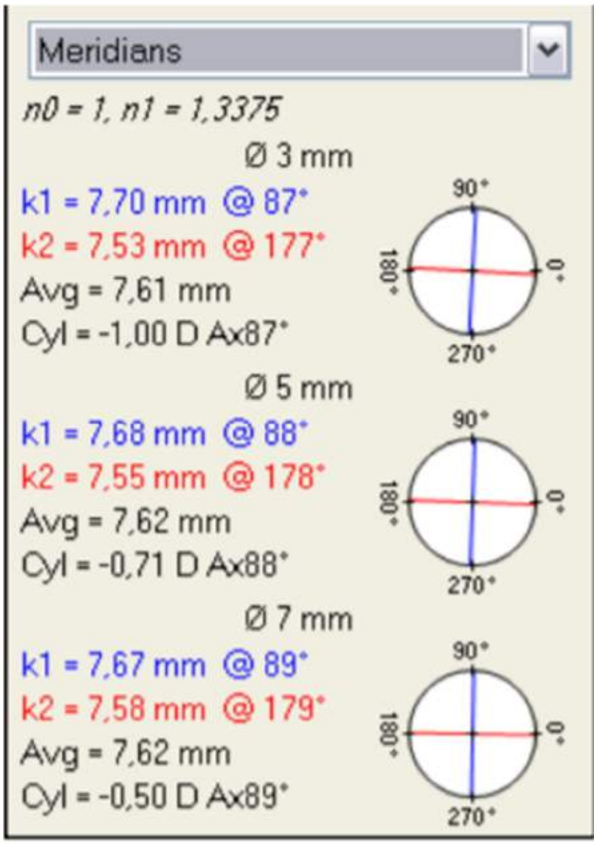
K2: the steepest meridian (in red) with its curvature, direction, and asphericity.

Avg: the mean curvature between K1 and K2.

Cyl: corneal toricity; that is, the difference between K1 and K2, in diopters, and the orientation of the negative cylinder.

MERIDIANS

Shows the curvature values for the meridians with the greatest and least curvature in the 3-mm,5-mm, and 7-mm zones of the cornea, forcing the axes into perpendicularity the one with the other.



SHAPE INDICES

Rf: Flat Radius Represents the radius of the curve that best approximates the curvature of the flattest meridian for the given diameter. Each radius value is associated with an asphericity value

Rs: Steep Radius Represents the radius of the curve that best approximates the curvature of the steepest meridian for the given diameter.

RMS (Root Mean Square)

This represents the deviation of the surface being examined from the aspherotoric

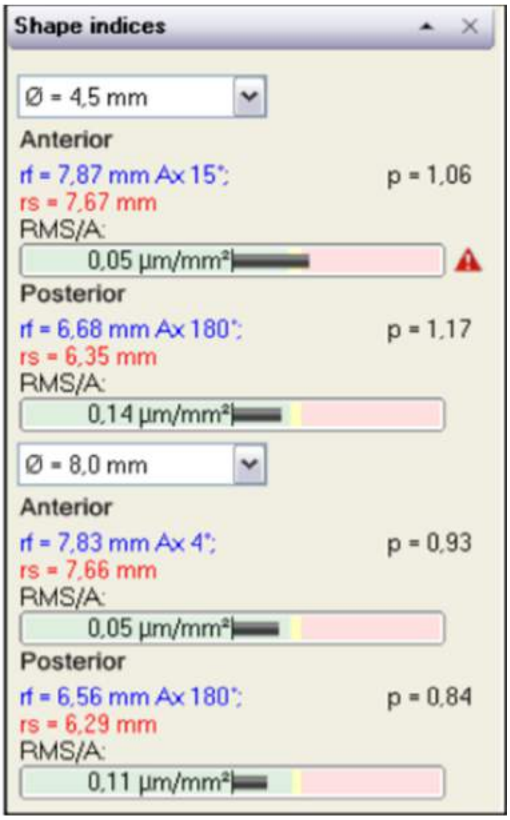
surface of best fit described by Rf, Rs and relative asphericity. If the RMS is low, the

surface of the cornea in the area delimited by the given diameter is very regular. The

higher the RMS, the more irregular the corneal surface.

RMS/A

Root Mean Square per unit surface Area.



KERATOREFRACTIVE INDICES

ASTIGMATISM

3 mm & 5 mm: corneal astigmatism, expressed in diopters, in an area of the cornea 3 mm & 5mm respectively in diameter and centered on the corneal vertex.These two values represent the cylinder and the axis of the regular astigmatism component for the two diameters. A difference in axis or power between the two diameters indicates an irregular astigmatism that cannot be efficaciously corrected with an ophthalmic lens.

Mean Pupil Power

Represents the mean axial curvature, expressed in diopters, of an entire portion of the cornea 3 mm in diameter and centered on the entrance pupil and takes into consideration the Stiles-Crawford effect; that is, greater weight is assigned to the central points. This parameter represents the sphere equivalent to the cornea in a 3 mm pupillary zone and is useful for defining the central mean curvature for irregular corneas such as those seen in cases of keratoconus, perforating keratoplasty, trauma, etc., or in highly aspherical corneas such as may be seen following refractive surgery.

Longitudinal Spherical Aberration

Longitudinal Spherical Aberration (LSA), expressed in diopters, in an area of the cornea 4.5 mm in diameter centered on the center of the pupil.

Irregularity of Curvature

Standard deviation (or root mean square, RMS) of the instantaneous curvature with respect to a best-fit aspherical surface, calculated for a 4.5 mm-diameter area of the cornea centered on the center of the pupil. This index is expressed in diopters. An irregularity index of 0 indicates a perfectly smooth surface approximating an aspherotoric reference surface.

Surface Asymmetry

The SAI (Surface Asymmetry Index) is the index of surface asymmetry of a 4.5 mm area of the cornea centered on the center of the pupil

KERATOCONUS SCREENING

A series of indices describing the morphology of the cornea, which are useful in diagnosis of keratoconus and in follow-ups.

- Tangential curvature of the anterior corneal surface on an 8 mm diameter zone
- Tangential curvature of the posterior corneal surface on an 8 mm diameter zone
- Anterior elevation respect to a best-fit reference asphero-toric surface
- Posterior elevation respect to a best-fit reference aspherotoric surface
- Difference of the corneal pachymetry and a normal‘ cornea

-Steepest point of the anterior surface (AKf – Apical KeratometryFRONT);

-Steepest point of the posterior surface (AKb – Apical KeratometryBACK);

-Highest point of ectasia on the anterior corneal surface (KVf – Keratoconus VertexFRONT);

-Highest point of ectasia on the posterior corneal surface

(KVb – Keratoconus VertexBACK);

-Thinnest point of cornea (ThkMin – Minimum Thickness).

- Curvature asymmetry

o **The Symmetry Index of the anterior curvature (**SIf – Symmetry Index FRONT) is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres.

SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one.

o **The Symmetry Index of the posterior curvature** (SIb – SymmetryIndexBACK) is defined as the difference of the mean posterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres.

The index is expressed in diopters

- The indices BCVf e BCVb allow the evaluation of the presence and of the state of an ectasia, through the analysis of the coma and trefoil components of Zernike‘s decomposition. The basic idea behind these indices is that the ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in the coma, trefoil, spherical aberration components of Zernike‘s decomposition of altimetry

- The index BCV or vectorial BCV is the vectorial sum of BCVf and BCVb. The basic idea is that in an eye with ectasia the anterior corneal surface is morphologically similar to the posterior corneal surface and the directions of both the vectors BCVf e BCVb are correlated.

KERATOCONUS SCREENING

- Normal
- Suspect keratoconus (a rather normal eye with changes typical of an initial ectasia in the posterior corneal surface)
- Keratoconus
- Abnormal or treated

In case of classification as Keratoconus compatible some further morphologic indices are shown:

- Steepest point of the anterior corneal surface

  (AKf – Apica Keratoscopy FRONT);

- Steepest point of the posterior corneal surface

  (AKb – Apical Keratoscopy BACK);

- Highest point of ectasia on the anterior corneal surface

  (KVf – Keratoconus Vertex FRONT);

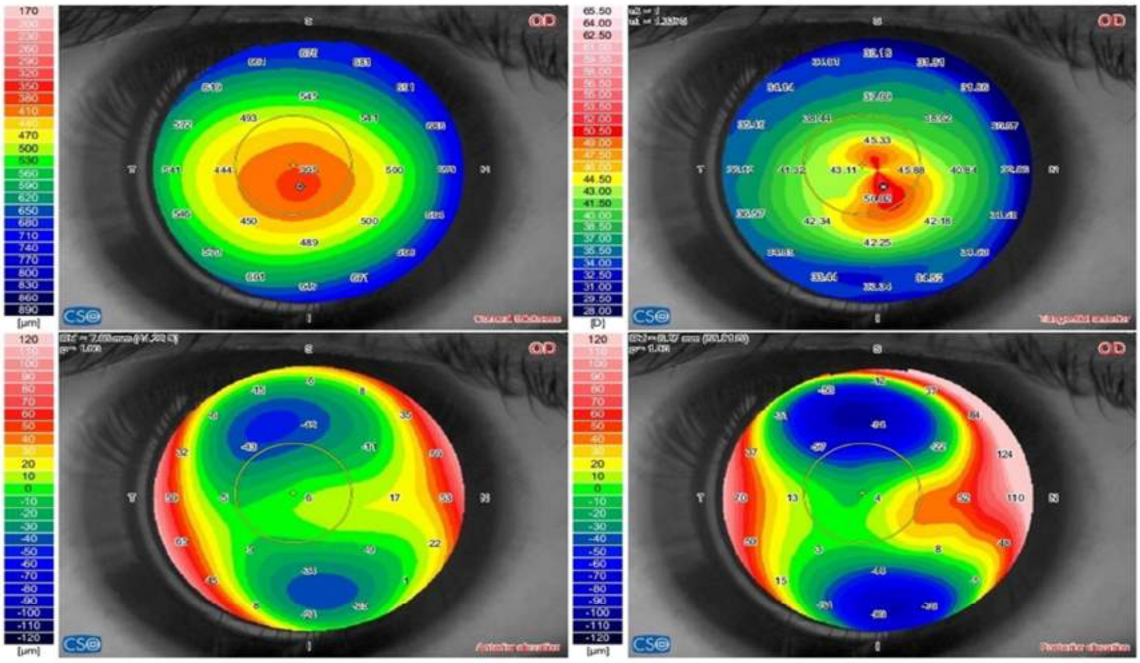
- Highest point of ectasia on the posterior corneal surface

  (KVb – Keratoconus Vertex BACK);

- Thinnest point of cornea (ThkMin – Minimum Thickness);

Area and volume of the ectasic zone;RMS/A and RMSb/A, root mean square value of the difference between the altimetry and an aspherotoric best fit surface in the 8 mm zone for both the anterior & posterior surfaces of cornea

SIRIUS TOPOGRAPHY
KERATOCONUS SUSPECT



Summary Indices

HVID* = 12.00 mm
Pupil (Topographic)
x = -0.46 mm, y = 0.18 mm
Ø = 3.38 mm
λ intercept: x = -1.14 mm, y = 0.45 mm
Thinnest location
x = -0.26 mm, y = -0.54 mm
Thk = 388 µm
Apex
x = 0.17 mm, y = -0.57 mm
Curv = 51.81 D
Anterior chamber
CCT + AD =
0.395 + 3.53 = 3.92 mm
Volume = 188 mm³
Iridocorneal angle = 46°
HACD = 12.37 mm
Lens rise = 0.06 mm
Corneal volume (Ø=10mm)
Volume = 49.6 mm³

K readings (n0 = 1, n1 = 1.3375)

	K1	K2	Avg	Cyl
Sim-k	K1 = 44.54 D @ 14°	K2 = 49.00 D @ 104°	Avg = 46.67 D	Cyl = -4.46 D Ax 14°
Anterior Ø=3mm	K1 = 44.94 D @ 9°	K2 = 50.76 D @ 99°	Avg = 47.67 D	Cyl = -5.81 D Ax 9°
Anterior Ø=5mm	K1 = 44.53 D @ 12°	K2 = 49.21 D @ 102°	Avg = 46.75 D	Cyl = -4.67 D Ax 12°
Anterior Ø=7mm	K1 = 43.88 D @ 13°	K2 = 47.58 D @ 103°	Avg = 45.66 D	Cyl = -3.70 D Ax 13°

K readings (n1 = 1.376, n2 = 1.336)

	K1	K2	Avg	Cyl
Posterior Ø=3mm	K1 = -5.89 D @ 1°	K2 = -7.53 D @ 91°	Avg = -6.61 D	Cyl = +1.65 D Ax 1°
Posterior Ø=5mm	K1 = -5.96 D @ 3°	K2 = -7.33 D @ 93°	Avg = -6.58 D	Cyl = +1.37 D Ax 3°
Posterior Ø=7mm	K1 = -6.02 D @ 6°	K2 = -7.03 D @ 96°	Avg = -6.49 D	Cyl = +1.01 D Ax 6°

Shape indices

	rf	rs	p	RMS/A
Anterior Ø=6.0mm	rf = 46.33 D Ax 11°	rs = 51.78 D	p = -0.65	RMS/A=0.15µm/mm²
Posterior Ø=6.0mm	rf = -6.18 D Ax 4°	rs = -7.34 D	p = 0.59	RMS/A=0.34µm/mm²
Anterior Ø=8.0mm	rf = 46.33 D Ax 14°	rs = 50.78 D	p = -0.38	RMS/A=0.15µm/mm²
Posterior Ø=8.0mm	rf = -6.36 D Ax 8°	rs = -7.24 D	p = 0.42	RMS/A=0.39µm/mm²

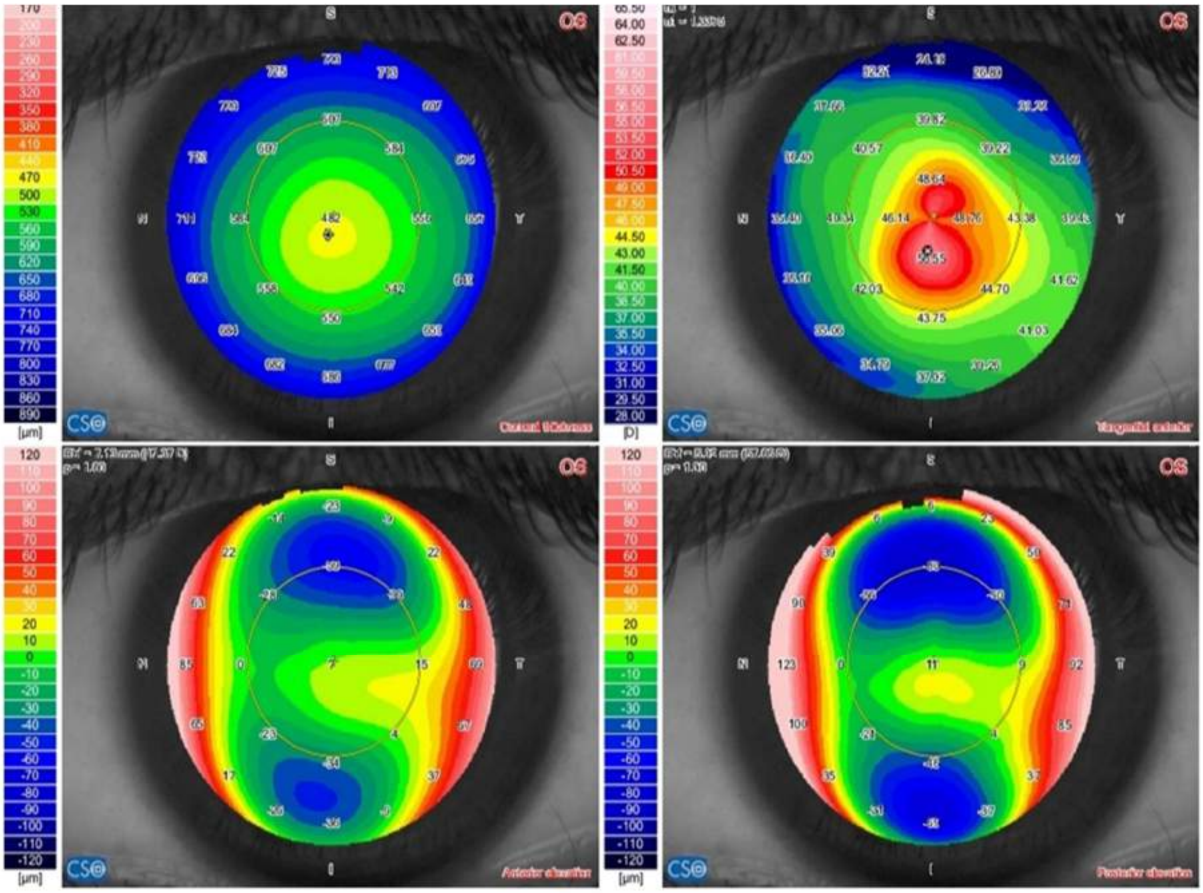
Refractive analysis

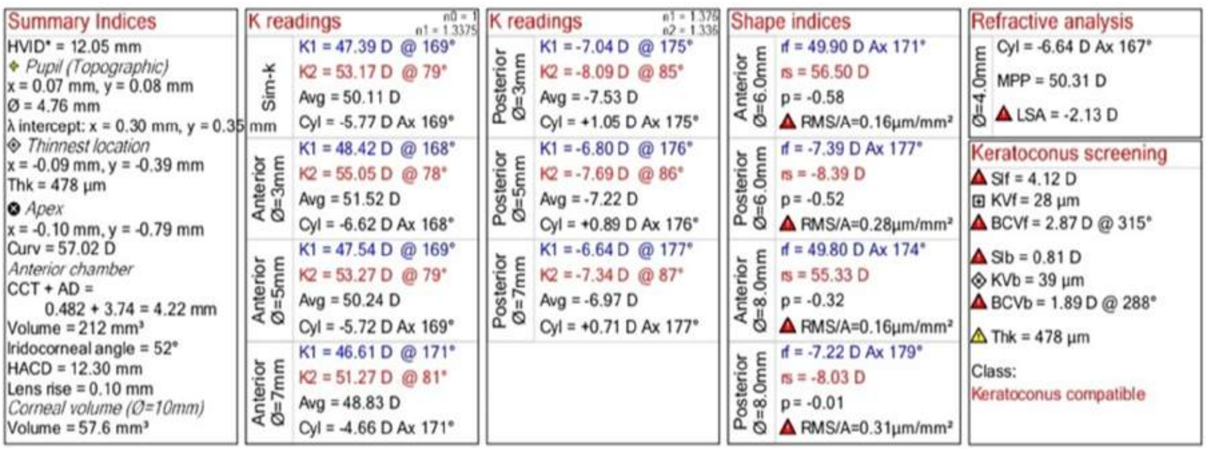
Ø=4.0mm
Cyl = -4.94 D Ax 11°
MPP = 45.86 D
LSA = -3.12 D

Keratoconus screening

SIf = 3.12 D
KVf = 23 µm
BCVf = 1.93 D @ 326°
SIb = 0.67 D
KVb = 37 µm
BCVb = 1.43 D @ 329°
Thk = 388 µm
Class:
- Suspect keratoconus

CLINICAL KERATOCONUS





Summary Indices

HVID* = 12.05 mm
Pupil (Topographic)
x = 0.07 mm, y = 0.08 mm
Ø = 4.76 mm
λ intercept: x = 0.30 mm, y = 0.35 mm
Thinnest location
x = -0.09 mm, y = -0.39 mm
Thk = 478 µm
Apex
x = -0.10 mm, y = -0.79 mm
Curv = 57.02 D
Anterior chamber
CCT + AD =
0.482 + 3.74 = 4.22 mm
Volume = 212 mm³
Iridocorneal angle = 52°
HACD = 12.30 mm
Lens rise = 0.10 mm
Corneal volume (Ø=10mm)
Volume = 57.6 mm³

K readings (n0 = 1, n1 = 1.3375)

Sim-k	K1 = 47.39 D @ 169° K2 = 53.17 D @ 79° Avg = 50.11 D Cyl = -5.77 D Ax 169°
Anterior Ø=3mm	K1 = 48.42 D @ 168° K2 = 55.05 D @ 78° Avg = 51.52 D Cyl = -6.62 D Ax 168°
Anterior Ø=5mm	K1 = 47.54 D @ 169° K2 = 53.27 D @ 79° Avg = 50.24 D Cyl = -5.72 D Ax 169°
Anterior Ø=7mm	K1 = 46.61 D @ 171° K2 = 51.27 D @ 81° Avg = 48.83 D Cyl = -4.66 D Ax 171°

K readings (n1 = 1.376, n2 = 1.336)

Posterior Ø=3mm	K1 = -7.04 D @ 175° K2 = -8.09 D @ 85° Avg = -7.53 D Cyl = +1.05 D Ax 175°
Posterior Ø=5mm	K1 = -6.80 D @ 176° K2 = -7.69 D @ 86° Avg = -7.22 D Cyl = +0.89 D Ax 176°
Posterior Ø=7mm	K1 = -6.64 D @ 177° K2 = -7.34 D @ 87° Avg = -6.97 D Cyl = +0.71 D Ax 177°

Shape indices

Anterior Ø=6.0mm	rf = 49.90 D Ax 171° rs = 56.50 D p = -0.58 RMS/A=0.16µm/mm²
Posterior Ø=6.0mm	rf = -7.39 D Ax 177° rs = -8.39 D p = -0.52 RMS/A=0.28µm/mm²
Anterior Ø=8.0mm	rf = 49.80 D Ax 174° rs = 55.33 D p = -0.32 RMS/A=0.16µm/mm²
Posterior Ø=8.0mm	rf = -7.22 D Ax 179° rs = -8.03 D p = -0.01 RMS/A=0.31µm/mm²

Refractive analysis

Ø=4.0mm	Cyl = -6.64 D Ax 167° MPP = 50.31 D LSA = -2.13 D

Keratoconus screening

SIf = 4.12 D
KVf = 28 µm
BCVf = 2.87 D @ 315°
SIb = 0.81 D
KVb = 39 µm
BCVb = 1.89 D @ 288°
Thk = 478 µm
Class:
Keratoconus compatible

CORNEAL TOPOGRAPHY IN COMMON CLINICAL SITUATIONS

1) CONTACT LENS (CL)-INDUCED CORNEAL WARPAGE:

It occurs directly as a result of the mechanical pressure exerted by the lens. Patients with corneal warpage may be asymptomatic and have reduced spectacle corrected acuity or contact lens intolerance. The changes are most persistent in rigid gas permeable (RGP) lenses wearers . Normal corneal topography patterns based on computer assisted videokeratography include central irregular astigmatism, changed axis of astigmatism, loss of normal progressive flattening from the center to the periphery and a correlation between the resting position of the CL and topographic pattern. Contact lens wear should cease six weeks prior to pre-operative assessment for hard or rigid lenses, and two weeks prior to soft contact lens fitting. Surgery is not advisable till stabilization of topography pattern.

2)POST-KERATOPLASTY: In highly irregular corneas, topography assessment using computer assisted videokeratography is more accurate than refraction or keratometry for determining axis of greatest astigmatism, and the axis of tight sutures. Prolate patterns of topography are commonly seen after single continuous suturing. Suture removals may affect decrease in astigmatism in bowtie patterns and not in oval/steep flat patterns.

3)CORNEAL ECTASIAS: Keratoconus and pellucid marginal degeneration (PMD) is characterized by presence of irregular astigmatism and inferior corneal steepening on topography. Corneal topography serves as one of the most sensitive methods for detection of early keratoconus, as it may provide the clinician with characteristic clues before clinical signs become evident. It is also imperative to be able to differentiate true early keratoconus from other similar conditions such as a normal cornea with asymmetric bowtie or contact lens-induced warpage. Corneal topography of mild inferior steepening with normal corneal thickness and no evident clinical signs of keratoconus is termed "keratoconus suspect" and needs apt attention of the clinician in decision making to proceed with refractive surgery. Terrien's marginal degeneration of the cornea is characterized on topography by noticeable flattening of the cornea with high against the rule astigmatism.

4)REFRACTIVE SURGERY: Refractive corneal procedures alter the central corneal curvature and hence the asphericity of the cornea. Myopic refractive ablation treatments flatten the central optical zone resulting in a cornea that is less prolate, or even oblate, while hyperopic treatment steepens the optical zone, causing the cornea to become increasingly prolate. Changes in corneal topography can be depicted in difference or subtraction maps in which a later map is subtracted from an earlier one. When topography is used to guide ablation, height maps are used so that the treatment can be applied to the peaks, rather than the steep sides, of any elevation. Myopic treatment zone is delineated by a central flattened zone while hyperopic correction shows central steepening surrounded by a ring of relative flattening at the edge of the treatment zone, where corneal tissue has been removed. Decentration is identified by comparing the first week post-operative map with a pre-operative map. Similar post-operative appearance may also be seen in pre-existing asymmetric astigmatism, or an asymmetrical healing response. Decentrations of large diameter (6 mm) optical zones tend to be clinically significant if greater than 1 mm, or in patients with relatively large pupils. Eight topographic patterns after PRK have been identified. Homogeneous pattern have least astigmatism. Those with regular patterns (homogeneous or toric) have better predictability & visual acuity than those with irregular patterns. The irregular patterns include semi-circular, central islands, focal irregularities and irregularly irregular. A central island is present when any part of the treatment zone is surrounded by areas of lesser curvature on more than half of its circumference. They are classified according to the power and diameter of the central steep area. The refractive and topographic changes after LASIK are similar to PRK, but the over-correction is not as large, and usually early stability is achieved. Decentration is more common and tends to be more significant. Epithelial in-growth at the periphery of the flap-stromal interface is characterized on topography by an area of steepening at the edge of the treatment zone, which can progress centrally.

5) TOPOGRAPHY IN KERATOCONUS

-It helps in detecting keratoconus before the appearance of slit lamp findings contact lens fitting in keratoconus is facilitated by topographic studies

-Videographic analysis is helpful in detecting cases of milder form of disease without any overt clinical signs called forme fruste

6)TOPOGRAPHY IN RADIAL KERATOTOMY

Preoperative topography reveals that corneas with same central curvature given by keratometer may have markedly different shapes ie prolate, oblate and spherical post operative topography reveals flattening of the entire cornea with only relative peripheral steepening contact lens fitting post RK

7)ROLE OF TOPOGRAPHY IN POST-KERATOPLASTY ASTIGMATISM

-Removal of tight sutures for control of post PK astigmatism

-Corneal relaxing incisions to control post PK astigmatism

-Post Penetrating keratoplasty cases for contact lens fitting by corneal topographic analysis

8)TOPOGRAPHY IN PRK & LASIK

-Decentration of ablation zone can be detected on postoperative topography

-Irregular ablation zones recognition has resulted in modification of procedures to prevent their occurrence

CLINICAL APPLICATIONS OF TOPOGRAPHIC DEVICES

- Role in diagnosis of corneal diseases keratoconus, epithelial dystrophies, terrien's & pellucid marginal degeneration
- Topography & contact lenses Corneal topographic analysis helps in giving a comfortable fit especially in rigid contact lens fitting thus providing maximum visual correction.
- It helps in early diagnosis of contact lens induced changes in cornea like central irregular astigmatism, corneal warpage and loss of radial symmetry.
- It helps in contact lens fit in difficult situations like post keratoplasty, keratoconus, post radial keratotomy
- Other applications of topography IOL calculation, laser pachymetry, corneal topographic analysis can be stored to show the pre and postoperative conditions for self-study & patient satisfaction purposes

LIMITATIONS OF TOPOGRAPHIC DEVICES

1)Algorithms for power calculation are based on spherical optical systems which may lead to qualitative and quantitative erroneous interpretations as the normal cornea is aspheric

2)The correlation between corneal curvature and power is valid for spheres and elliptical surfaces as long as there are no areas of abrupt transition in corneal curvature

3) Data are averaged across meridians thus tending to magnify the blend zones rather than show the sharp boundaries

4)The formulae employed for power calculation are centered on the corneal apex and not on the more relevant line of sight.

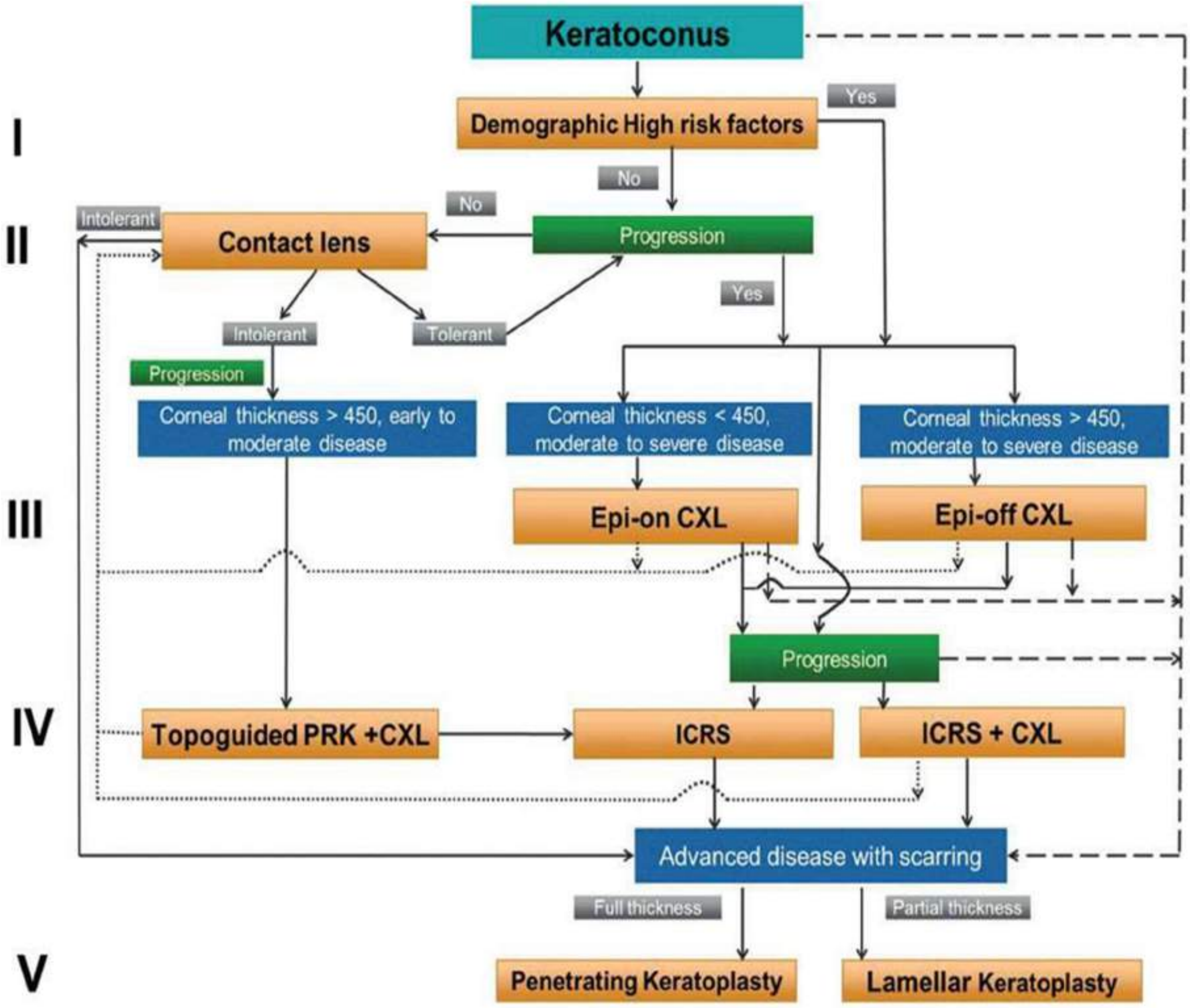
5)Central corneal power is interpolated from the central rings and it may give overestimations in cases of oblate corneas.

6)The keratometric index of refraction usually employed underestimates the changes in corneal power after procedures like PRK may not show a change in corneal topography based on corneal surface although a change in corneal thickness has taken place.

TREATMENT:

- Spectacle correction
- Contact lens (Rigid gas permeable lens, scleral contact lenses, semiscleral, Rose K lenses, piggyback contact lenses, hybrid lenses, sooper lens)
- Corneal collagen cross linking (CXL or C3R)
- Intra stromal corneal ring segments (ICRS or Intacs)
- Corneal allogenic intrastromal ring segments (CAIRS)
- Phakic IOL
- LASIK Xtra
- Thermokeratoplasty
- Keratoplasty (DALK. PK. Bowmans membrane transplantation)

FIVE-POINT MANAGEMENT ALGORITHM FOR KERATOCONUS



DIFFERENTIAL DIAGNOSIS

- Keratoglobus
- Posterior Keratoconus
- Pellucid Marginal Degeneration
- Contact lens-induced corneal warpage
- Corneal ectasia post-refractive laser treatment

REVIEW OF LITERATURE

In **2014** October , **J. Buhren** proposed corneal scheimpflug topography as the most important imaging technique for the anterior segment of the eye in keratoconus patients.

In **2016** June , **Bernardo T Lopes** proposed that Pentacam – corneal and anterior segment topographer gives a comprehensive analysis of 3D corneal geometry. With this device, the detection of mild keratoconus or ectasia susceptibility is possible

In **2017** September by **Rohit Shetty, Harsha Rao, pooja khamar** proposed keratoconus screening indices and their diagnostic ability to distinguish normal from ectatic corneas and compared the diagnostic ability of 3 Scheimpflug devices

In **2018** September by **Samira Huseynli** proposed, the parameter values can effectively differentiate subclinical keratoconus and clinical keratoconus from non keratoconic thin corneas.

In **2020** July by **Gracia Castro – Luna and Antonio Perez – Rueda** proposed a model for early diagnosis of keratoconus and also described corneal thickness values as a tool to differentiate subclinical keratoconus and clinical keratoconus from non keratoconic thin corneas

In **2021** February by **Hesham Mohamed Gharieb , Ihab Saad Othman, Ahmed Hamdy Oreaba, Mona Kamal Abdelatif** demonstrated that Sirius scheimpflug topographer showed high predictive accuracy in detection of keratoconus and keratoconus indices for diagnosis of keratoconus by a combined placido and scheimpflug topography system

In **2021** june by **Bharat Gurnani, Kirandeep kaur, Prasanna et al** proposed the accuracy of scheimpflug imaging(Sirius) in detecting subclinical keratoconus and the high precision, sensitivity, and specificity, amongst eyes with clinical keratoconus and subclinical keratoconus from normal eyes.in discriminating among eyes with keratoconus or subclinical keratoconus from normal eyes.

PART B

AIM & OBJECTIVES

To study the diagnostic ability of scheimpflug device in differentiating subclinical from clinical keratoconus

Primary objective: To study the diagnostic ability of scheimpflug imaging

Secondary objective: To compare symmetry index back in subclinical and clinical keratoconus

Study centre: Cornea services, Regional Institute of ophthalmology and government ophthalmic hospital, Chennai – 600008.

Study design: Prospective analytical study.

Study period: Feb 2021 to Jan 2022

Sample size: 72 cases (36 subclinical keratoconus cases & 36 clinical keratoconus cases)

METHODOLOGY (MATERIAL AND METHODS)

1)All Patients diagnosed as subclinical and clinical keratoconus who presented to cornea clinic at RIOGOH from Feburary 2021 to January 2022 were registered and evaluated after obtaining informed consent.

2)A detailed history of the patients were taken and they were subjected to a thorough ocular examination including best corrected visual acuity (using Snellen charts), a proper refraction followed by anterior segment examination using slit lamp, ophthalmoscopic examination , retinoscopic examination, keratometry & pachymetry.

3)Corneal topographic examination were carried out using Scheimpflug with eye aligned to the visual axis by a central fixation light of the machine. patients were asked to blink before each scan was taken. Scans which had a quality specifications of “OK” were taken for analysis ,low quality and unacceptable scans were deleted and measurements were retaken.

4)Based on keratoconus screening index (symmetry index back) provided by Sirius scheimpflug imaging, eyes were classified into 2 groups as subclinical keratoconus and clinical keratoconus and its diagnosing ability were analysed.

Inclusion criteria

SUB CLINICAL KERATOCONUS:

1)Age between 12 to 46 years, Gender- male & female

2)Normal appearing cornea on slit lamp , keratometry ,Retinoscopy and ophthalmoscopy.

3)Simple & compound astigmatism (with/against the rule astigmatism) of -2.00D &above.

4)Inferior-Superior asymmetry / Bow-tie pattern with skewed radial axes on curvature map of videokeratoscopy.

CLINICAL KERATOCONUS:

1)Age between 12 to 46 years , Gender- male & female

2)An irregular cornea, determined by distorted keratometry mires/ distortion of retinoscopic or ophthalmoscopic red reflex.

3)At least 1 of the following biomicroscopic signs:

Vogt striae; Fleischer ring or corneal scarring consistent with keratoconus

Exclusion criteria

1)previous ocular surgeries

2)corneal scarring

3)Ocular Trauma

4)Glaucoma

5)Non corneal causes of astigmatism

6)Any other active ocular disease

Study parameters

1)visual acuity assessment using Snellen chart (uncorrected and best corrected)

2)Slit lamp biomicroscopy of anterior segment

3)Retinoscopy

4)Keratometry

5)Ophthalmoscopic examination (Direct & Indirect)

6)Pachymetry

7)Sirius topography

OBSERVATION AND RESULTS

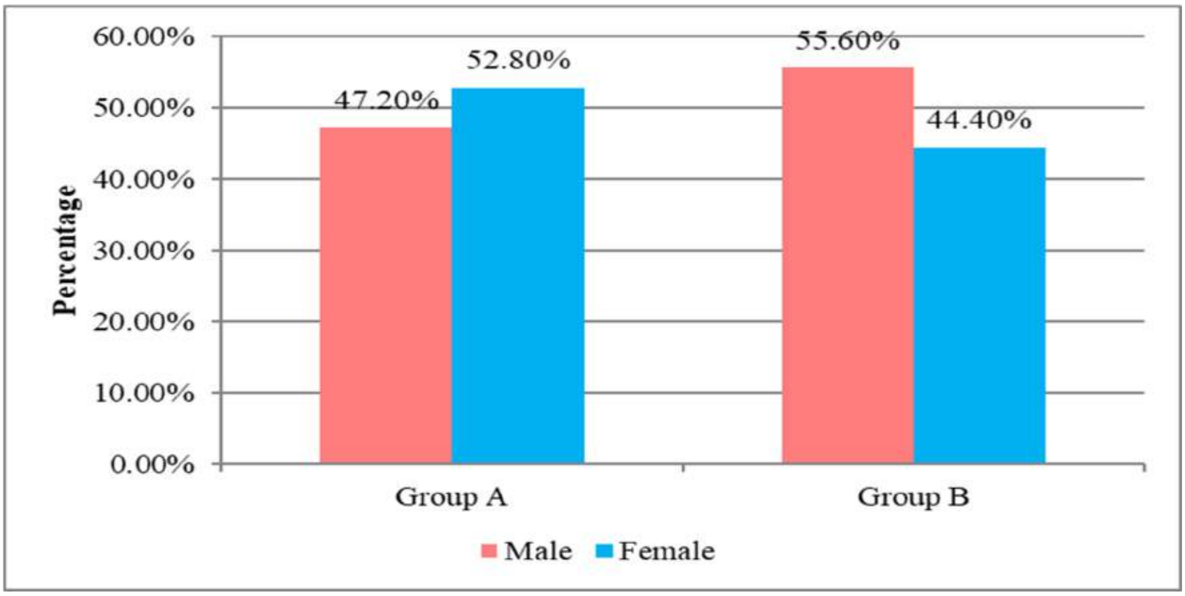
Table 1: Descriptive analysis of study group in study population (N=108)

Study group	Frequency	Percentage
Group A (Clinical)	36	50%
Group B (Suspect)	36	50%
Total	72	100%

The above table shows a descriptive analysis of 72 patients screened as Group A (36 clinical keratoconus cases) & Group B (36 suspect keratoconus cases).

Table 2: Comparison of gender with two group (N=72)

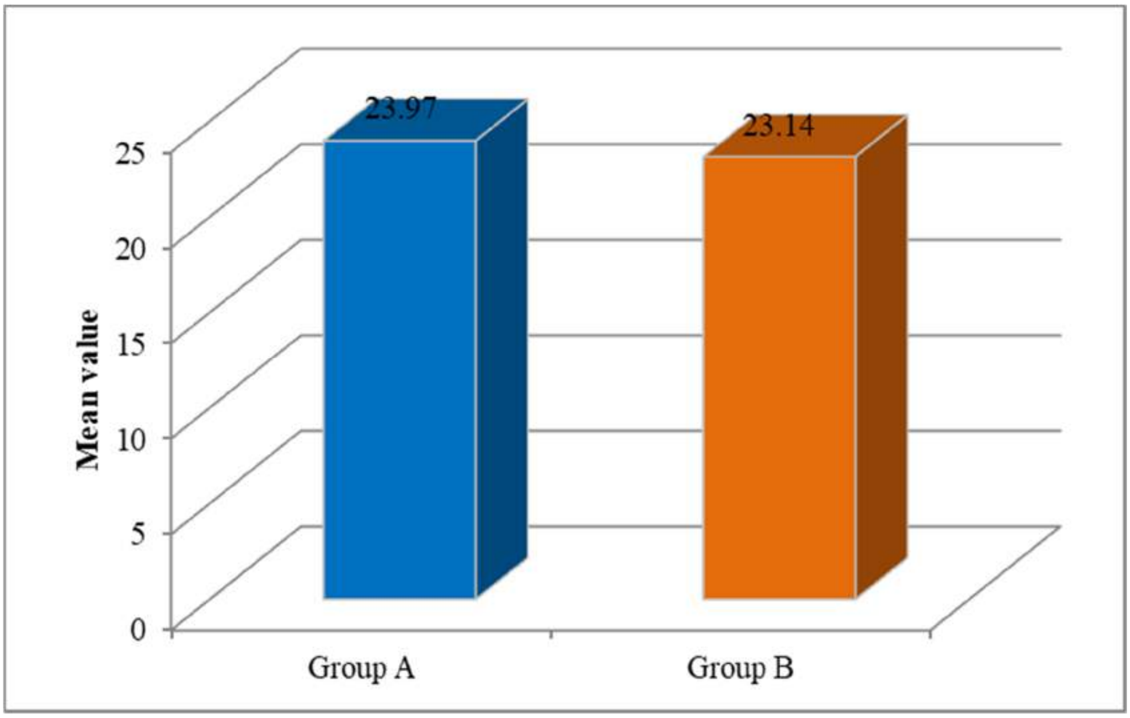
Gender	Group A	Group B	Total
Male	17 (47.2%)	20 (55.6%)	37 (51.4%)
Female	19 (52.8%)	16 (44.4%)	35 (48.6%)
Total	36 (100%)	36 (100%)	72 (100%)
P value	0.479 - Insignificant		



The above table & bar graph shows the comparison of gender between the two groups using chi-square test and the p value was found to be 0.47 which is insignificant in the study

Table 3: Comparison of mean age between two group (N=72)

	Group A	Group B	Unpaired t test P value
Age	23.97 ± 6.03	23.14 ± 7.48	0.604



The above table & bar graph shows the comparison of mean age between the two groups Group A (23.97 ± 6.03 & Group B(23.14 ± 7.48) using Unpaired t test and the p value was found to be 0.604 which is statistically insignificant in the study

Table 4: Comparison of age group with two group (N=72)

Age group	Group A	Group B	Total
<30	12 (33.3%)	14 (38.9%)	26 (36.1%)
31-40	20 (55.6%)	18 (50%)	38 (52.8%)
>41	4 (11.1%)	4 (11.1%)	8 (11.1%)
Total	36 (100%)	36 (100%)	72 (100%)
P value	0.878 - Insignificant		

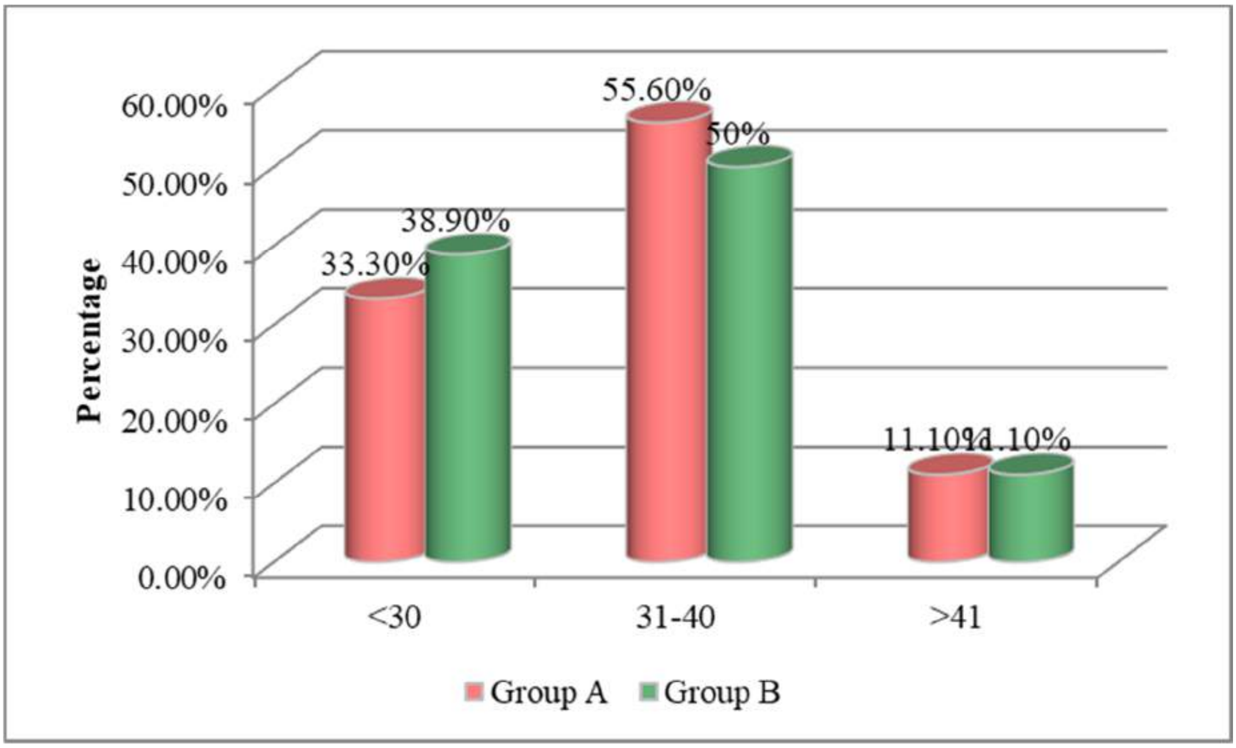
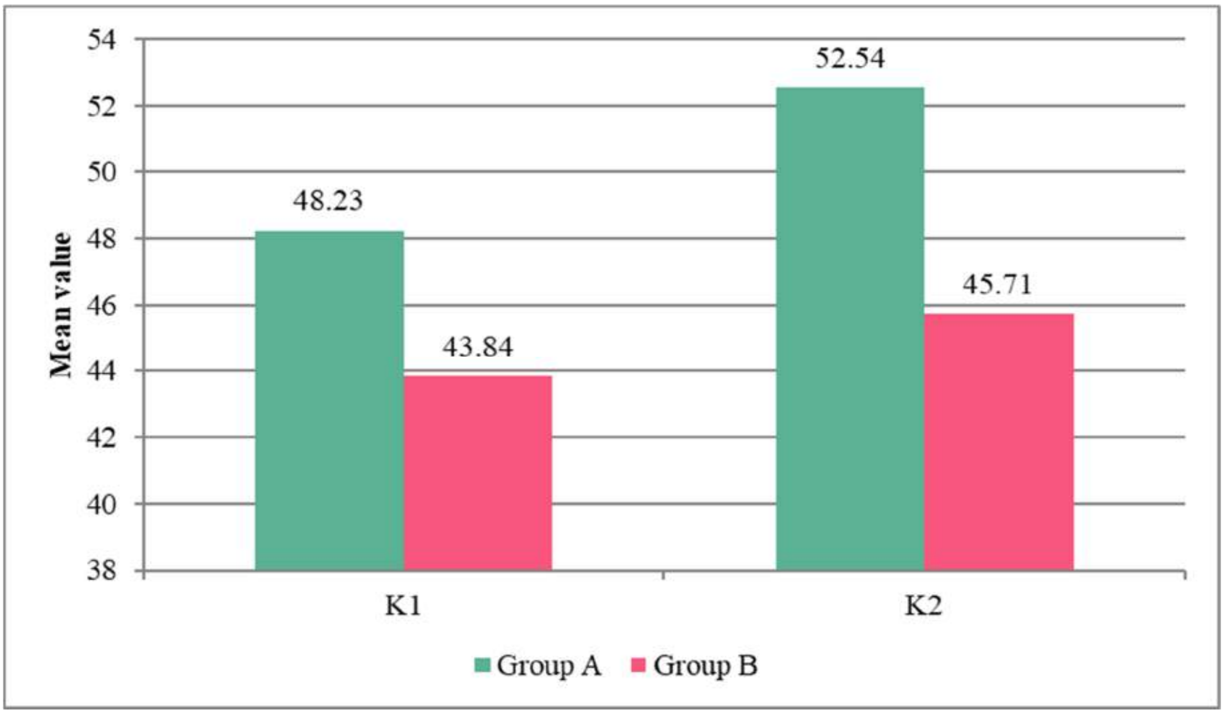


Table 5: Comparison of mean Keratometry values between two group Right eye(N=72)

Keratometry values Right eye	Group A	Group B	Unpaired t test P value
K1	48.23 ± 3.99	43.84 ± 2.29	<0.001
K2	52.54 ± 5.11	45.71 ± 3.38	<0.001

P Value of <0.05 is statistically significant

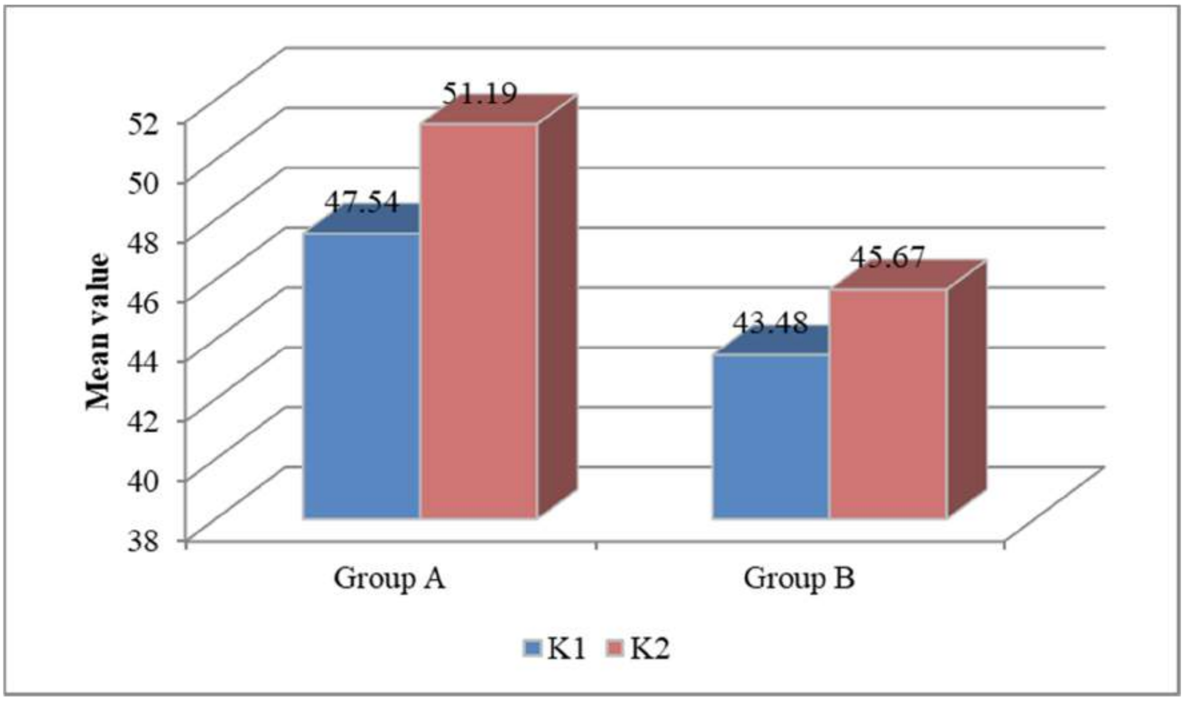


The above table & bar graph shows the comparison of mean keratometry values between the two groups in right eye Group A (K1 =48.23 ± 3.99, K2 =52.54 ± 5.11) Group B (K1=43.84 ± 2.29,K2= 45.71 ± 3.38) using Unpaired t test and the p value was found to be < 0.001 which is statistically significant in the study

Table 6: Comparison of mean Keratometry values between two group in left eye (N=72)

Keratometry values Left Eye	Group A	Group B	Unpaired t test P value
K1	47.54 ± 4.03	43.48 ± 2.42	<0.001
K2	51.19 ± 5.52	45.67 ± 4.13	<0.001

P Value of <0.05 is statistically significant



The above table & bar graph shows the comparison of mean keratometry values between the two groups in left eye Group A (K1 =47.54 ± 4.03, K2 =51.19 ± 5.52) Group B (K1=43.48 ± 2.42,K2=45.67 ± 4.13) using Unpaired t test and the p value was found to be < 0.001 which is statistically significant in the study

Table 7: Comparison of mean Pachymetry value between two group (N=72)

Pachymetry value	Group A	Group B	Unpaired t test P value
RE (microns)	460.24 ± 38.46	504.17 ± 37.75	<0.001
LE (microns)	484.19 ± 58.87	497.12 ± 34.50	0.336

P Value of <0.05 is statistically significant

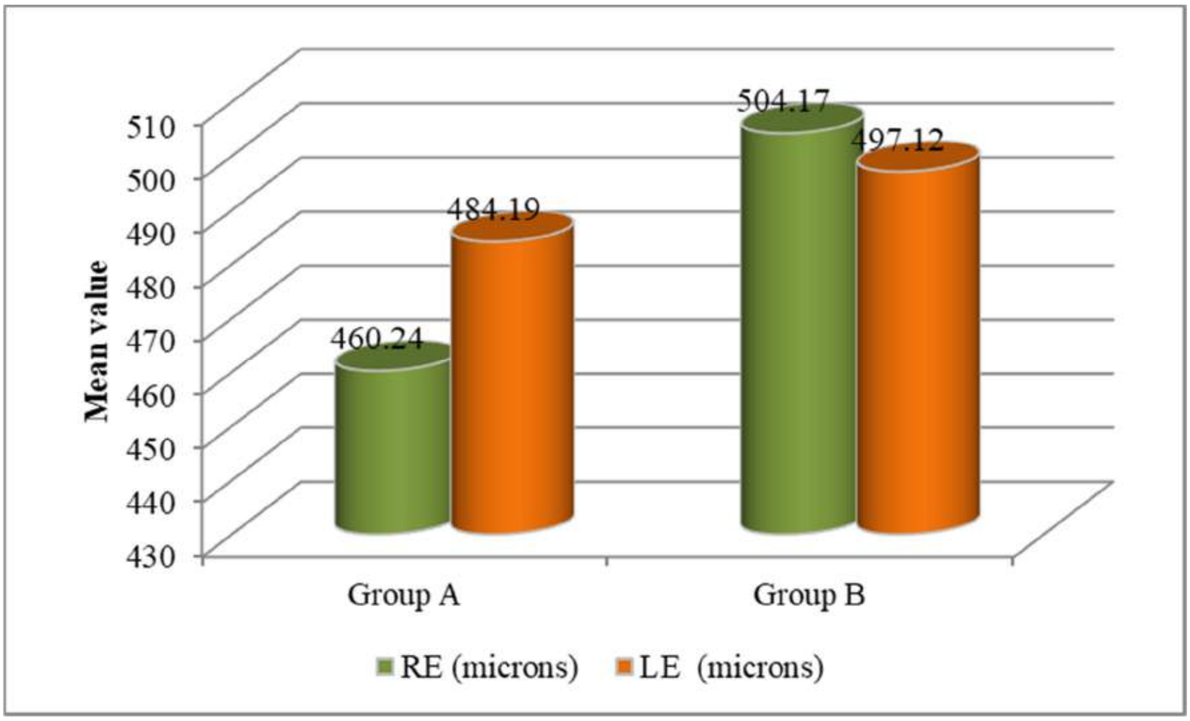
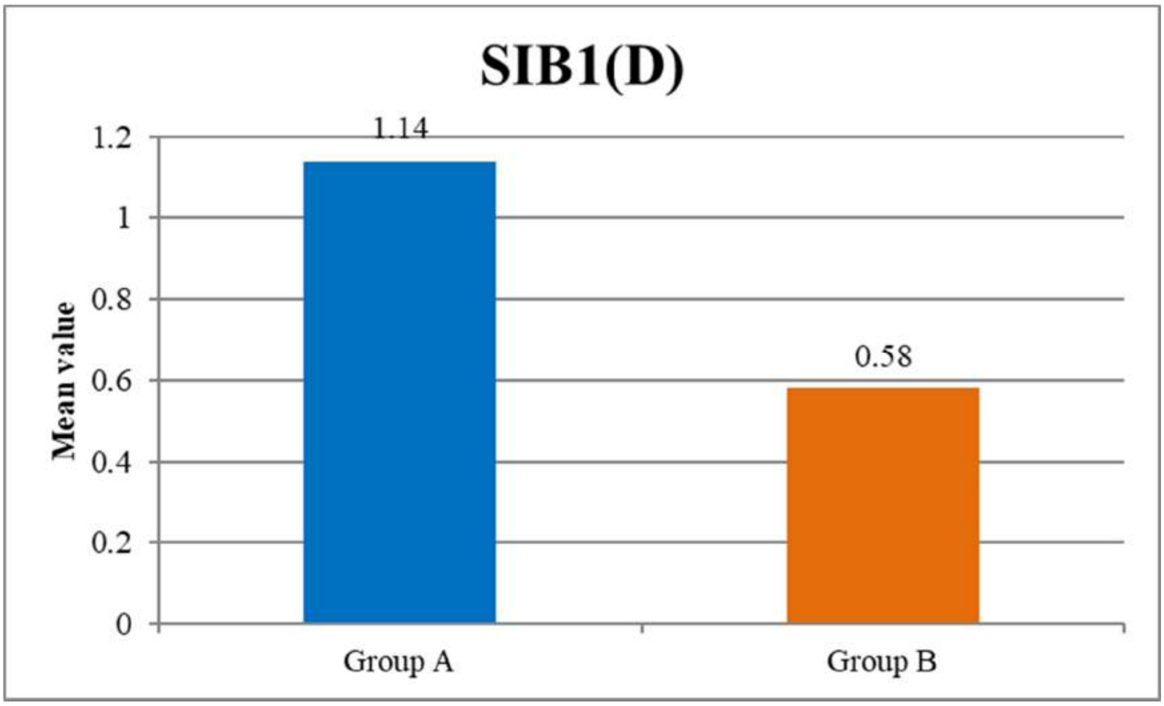


Table 8: Comparison of mean SIB right eye between two group (N=72)

	Group A	Group B	Unpaired t test P value
SIB1(D)	1.14 ± 0.91	0.58 ± 0.33	0.004

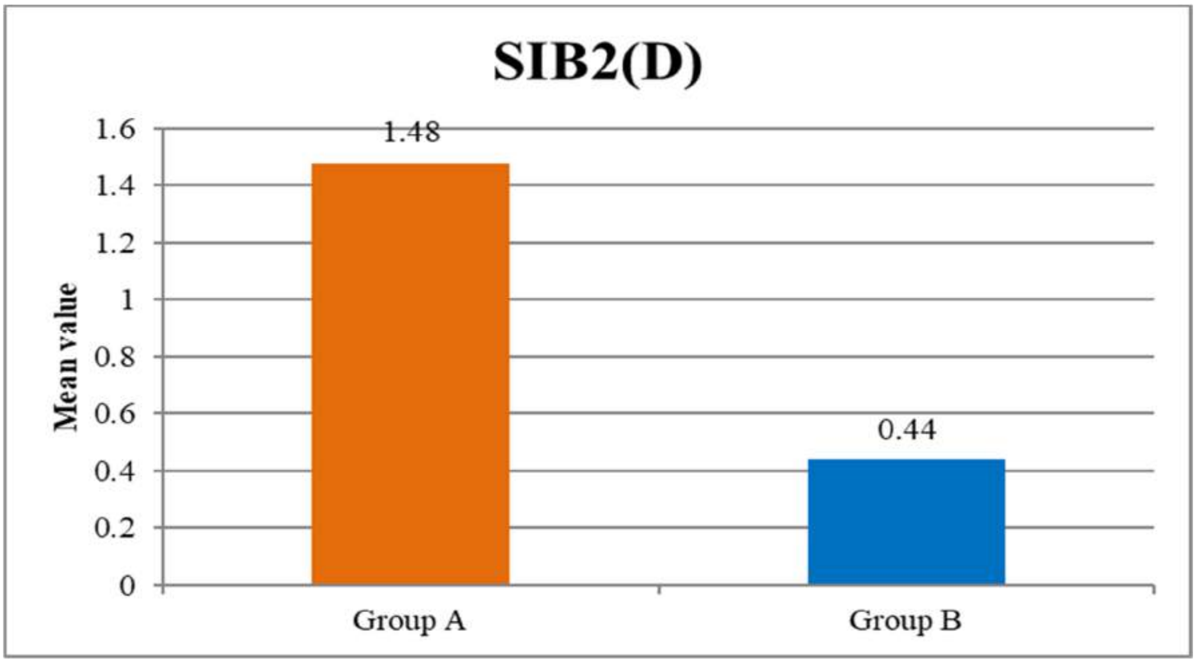


The above table & bar graph shows the comparison of mean sib values between the two groups in right eye Group A (1.14 ± 0.91) ,Group B (0.58 ± 0.33)using Unpaired t test and the p value was found to be 0.004 which is statistically significant in the study

Table 9: Comparison of mean left eye between two group (N=72)

	Group A	Group B	Unpaired t test P value
SIB2(D)	1.48 ± 1.11	0.44 ± 0.32	<0.001

P Value of <0.05 is statistically significant



The above table & bar graph shows the comparison of mean sib values between the two groups in left eye Group A (1.48 ± 1.11), Group B (0.44 ± 0.32)using Unpaired t test and the p value was found to be <0.001which is statistically significant in the study

Table 10:

	Group A	**Group B**
SIB(D)	1.31	0.51

DISCUSSION

Keratoconus screening index (SIB) in subclinical cases and compatible keratoconus cases were analysed. The current study reports the characteristics of symmetry index back(SIB) values measured with the Sirius Scheimpflug analyzer and differentiates between the subclinical keratoconus and clinical keratoconus .

In the study by Rohit Shetty et al highest sensitivity was seen for SIF (29.7%) & highest specificity was seen for SIB (100%).

It is of the essence to look through the indices on the topographic display after reading the map as it will give insight toward subclinical keratoconus. The first step would be to assess the quality of acquisition before interpretation.

To the best of our knowledge, only this study has reported concerns about the performance of the Sirius Scheimpflug analyzer in eyes with subclinical and clinical keratoconus.

A literature search did not provide many previous studies comparing keratoconus screening indices of the Sirius topographer.

CONCLUSION

The Keratoconus screening indices provided by Sirius topographer (scheimpflug imaging) helps in early detection of keratoconus .

These indices are reliable and can be used as stand alone to detect keratoconus and also to differentiate among normal cases, subclinical keratoconus and clinical keratoconus cases.

It provides a comprehensive corneal analysis used for preoperative refractive screening which includes information from the posterior cornea and full pachymetric data.

This added information improves the ability of the refractive surgeon to screen patients for occult ectatic disease or to identify patients potentially at higher risk for post laser-assisted in situ keratomileusis (LASIK) ectasia.

The versatility, precision and easy handling of Scheimpflug tomography is the most important imaging technique for the anterior segment of the eye

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PROFORMA

NAME: Hospital OP no:

AGE: Yrs SEX: M F

ADDRESS: Phone No:

CHIEF COMPLAINTS:

- Defective vision/Distortion of vision
- Frequent change of glasses
- Glare
- Photophobia
- watering
- Ocular irritation
- Coloured halos
- Diplopia

HISTORY OF PRESENT ILLNESS:

1.ONSET OF AGE NOTICED ON MODE (SUDDEN / GRADUAL) :

2. DURATION AND PROGRESSION:

3. PRE-DISPOSING FACTORS/ RISK FACTORS:

- History of atopy
- History of contact lens wear
- History of frequent eye rubbing

4.ASSOCIATED SYSTEMIC DISORDERS

(Chromosomal/connective tissue disorders):

5.ASSOCIATED OCULAR DISORDERS:

(congenital/Developmental/Genetic/allergic disorders):

6.PAST HISTORY:

- Diabetes mellitus
- Hypertension
- Bronchial asthma
- Ocular trauma
- Ocular surgeries

7.FAMILY HISTORY:

8.TREATMENT HISTORY:

9.GENERAL PHYSICAL EXAMINATION:

10)OCULAR EXAMINATION:

RIGHT EYE	OCULAR EXAMINATION	LEFT EYE
	LIDS AND ADNEXA	
	PALPEBRALCONJUNCTIVA	
	EOM	
	CONJUNCTIVA	
	CORNEA	
	ANTERIOR CHAMBER	
	PUPIL SIZE	
	LENS	
	VISUAL ACUITY (WITH/W/O GLASSES)	
	INTRAOCULAR PRESSURE	

11)OTHER SYSTEM INVOLVEMENT:

- CVS
- RS
- CNS
- ABDOMEN

12)INVESTIGATIONS:

•Visual acuity assessment using Snellen chart (uncorrected and best corrected)

•Ophthalmoscopic examination (Direct & Indirect)

•Retinoscopy

•Keratometry

•Pachymetry

•Sirius topography

13)DIAGNOSIS:

Consent:

I ……………….. aged……..S/O D/O

W/O…………………………….......

was clearly explained about the disease condition and the proposed

treatment procedure and fully consent for the same

Sign of patient   Sign of relative

ABBREVATIONS

KC	-	KERATOCONUS
AB	-	ASYMMETRIC BOW TIE
SRAX	-	SKEWED RADIAL AXES
SAI	-	SURFACE ASYMMETRY INDEX
SIF	-	SYMMETRY INDEX FRONT
SIB	-	SYMMETRY INDEX BACK
AKf	-	APICAL KERATOMETRY FRONT
AKb	-	APICAL KERATOMETRY BACK
KVf	-	KERATOCONUS VERTEX FRONT
KVb	-	KERATOCONUS VERTEX BACK
ThkMin	-	MINIMUM THICKNESS
RMS/A &B	-	ROOT MEAN SQUARE VALUE
LSA	-	LONGITUDINAL SPHERICAL ABBERATION
BCVf	-	BAIOCCHI-CALOSSI-VERSACI FRONT
BCVb	-	BAIOCCHI-CALOSSI-VERSACI BACK

KEY TO MASTER CHART

RE	-	Right Eye
LE	-	Left Eye
BE	-	Both Eye
K1	-	Horizontal Corneal Curvature
K2	-	Vertical corneal curvature
SIB	-	Symmetry Index Back
SIb1	-	Symmetry Index Back for RE
SIb2	-	Symmetry Index Back for LE
D	-	Diopter
µm	-	Micrometer

MASTER CHART CLINICAL KERATOCONUS

S.no	Age	Sex	KERATOMETRY VALUES				Pachymetry	Pachymetry	RIGHT EYE	LEFT EYE
			RE K1	RE K2	LE K1	LE K2	RE	LE	SIB1(D)	SIB2(D)
1	20	F	49.99D @5	54.55@95	54.60D@168	62.00@78	492microns	468microns	0.91D	0.90D
2	20	F	49.99D @5	54.55@95	54.60D@168	62.00@78	492microns	468microns	0.91D	0.90D
3	17	F	45.32D@11	49.15D @101	44.86D@173	47.67D@83	505microns	521microns	1.04D	3.32D@243
4	17	F	45.32D@11	49.15D @101	44.86D@173	47.67D@83	505microns	521microns	1.04D	3.32D@243
5	25	M	49.10D@16	56.41D@106	48.30D@31	49.06D@121	451microns	647microns	-0.53D	-0.28D
6	14	F	52.37D@21	56.78D@117	....	.....	411microns	.....	1.16D	....
7	18	M	49.32D@146	52.87D@56	.....	....	404microns	.....	1.13D	.....
8	16	M	62.52D@161	71.52D@71	59.00D@0	66.84@90	367microns	330microns	-0.67D	-1.44D
9	29	M	46.72D@37	50.06D@127	50.75D@4	51.78D@94	461microns	450microns	1.97D	2.41D
10	29	M	46.72D@37	50.06D@127	50.75D@4	51.78D@94	461microns	450microns	1.97D	2.41D
11	25	M			45.80D@22	48.43D@112	....	....	....	0.08D
12	34	F	48.15D@28	50.83D@118	49.10D@143	52.15D@53	483microns	467microns	1.30D	1.93D
13	34	f	48.15D@28	50.83D@118	49.10D@143	52.15D@53	483microns	467microns	1.30D	1.93D
14	30	f	47.23D@33	50.78D@123	46.20D@147	49.53D@57	485microns	493microns	0.76D	1.05D
15	20	f	...	....	44.43D@177	47.48D@87	....	535microns	....	1.63 D
16	23	f	...	....	52.12D@162	59.48D@72	.....	454microns	.....	0.68D
17	20	f	.....	....	44.74D@109	47.71D@19	.....	502microns	.....	0.92D
18	30	M	45.29D@174	48.11D@84	.....	.....	493microns	....	1.55D	....
19	25	M	....	.....	49.05D@145	57.11D@59	...	484microns	....	3.50D
20	25	M	52.69D@22	59.19D@112	.....	.....	459microns		2.94D	....
21	22	M	....	....	44.06D@173	46.60D@83		464microns	....	0.87D
22	21	M	45.68D@42	51.71D@132	....	.....	494microns		1.11D	....
23	30	M	.....	....	45.96D@7	50.01D@92	....	489microns	....	1.94D
24	22	F	....	....	45.61D@167	48.39D@77	....	458microns	....	1.33D
25	26	F	....	....	42.82D@170	45.66D@80	....	627microns	....	0.60D
26	22	F	45.10D@14	48.13D@104	....	.....	463microns	....	0.89D	....
27	30	F	47.98D@40	53.06D@130	....	....	431microns	....	2.53D	....
28	15	M	....	....	45.29D@171	48.21D@81	....	515microns		0.55D
29	15	M	48.76D@160	51.19D@70	....	.....	482microns	....	-0.69D	.....
30	18	m	.....	....	46.02D@163	48.29D@73	.....	479microns	....	2.41D
31	21	F	41.95D@59	45.20D@149	41.24D@118	45.72D@28	478microns	471microns	1.94D	1.86D
32	25	F	46.00D@35	50.74D@125	46.31D@145	49.31D@55	479microns	493microns	2.43D	2.19D
33	27	F	44.48D@06	49.79D@96	44.06D@178	46.60D@83	434microns	452microns	0.09D	0.87D
34	38	F	45.32D@11	49.15D@101	44.86D@178	47.67D@83	494microns	503microns	1.04D	1.59D
35	29	M	52.35D@27	56.78D@117	50.66D@134	55.66D@44	395microns	420microns	1.16D	1.52D
36	31	M	49.32D@146	52.87D@56	46.02D@168	48.29D@73	404microns	445microns	1.13D	2.41D

MASTER CHART SUBCLINICAL KERATOCONUS

S.no	Age	Sex	Keratometry values				Pachymetry values		RIGHT EYE	LEFT EYE
			RE K1	RE K2	LE K1	LE K2	RE	LE	SIB1(D)	SIB2(D)
1	22	F	43.78D@42	45.21D@132	.....	......	499microns	...	0.80D	....
2	24	M	40.96D@23	41.43D@113	40.90D@165	41.09D@75	523microns	504microns	0.16D	0.30D
3	25	M	42.67D@47	44.65D@137	.....	.....	531microns	....	0.63D	....
4	27	M	....	......	41.69D@106	42.09D@16		496microns	....	0.18D
5	24	M	44.71D@95	45.10D@5	.....	.....	551microns		0.83D	....
6	20	M	39.81D@9	40.05D@99	.....	.....	550microns		0.21D	....
7	30	F	47.23D@33	50.78D@123	46.20D@147	49.53D@57	485microns	493microns	0.76D	1.05D
8	20	F	44.95D@10	46.56D@100	.....	.....	534microns		0.92D	....
9	22	F	47.10D@24	49.78@114	52.12D@162	59.48D@72	482microns	454microns	0.46D	0.68D
10	21	F	42.47D@5	42.98D@95	42.81D@11	43.51D@101	528microns	528microns	0.07D	0.07D
11	17	F	40.83D@85	41.44D@175	.....	.....	572microns	.....	1.41D	....
12	16	m	44.41D@12	50.84D@102	.....	.....	454Microns	.....	0.32D	....
13	16	m	.....	.....	44.37D@165	48.64D@65	....	474microns	....	0.23D
14	18	m	43.21D@36	46.40@126	.....	.....	522microns	....	0.68D	
15	18	m	.....	.....	43.22D@24	44.53D@114	....	528microns	....	0.44D
16	31	f	44.70D@3	47.14D@93	.....	.....	....	493microns	....	0.03D
17	16	M	....	.....	41.42D@152	45.64D@62	....	516microns	....	0.27D
18	22	M	45.50D@8	47.22D@98			488microns	.....	0.60D	....
19	28	F	....	.....	43.94D@179	46.54D@89	....	519microns	....	0.31D
20	30	M	43.63D@22	45.55D@112	....	....	501microns	....	0.94D	....
21	27	M	.....	...	43.89D@172	44.72D@82	.....	488microns	....	0.29D
22	31	M	42.67D@53	48.45D@183	41.57D@115	42.21D@25	486microns	528microns	0.62D	0.30D
23	23	F	47.67D@47	44.45D@13	44.96D@14	48.97D@104	494microns	501microns	0.18D	0.3D
24	25	M	41.69D@106	42.08D@16	40.90D@165	41.09D@75	531microns	365microns	0.63D	1.23D
25	46	M	44.41D@12	50.84D@102	44.35D@165	48.64D@75	523microns	489microns	0.92D	0.94D
26	25	F	41.69D@106	42.08D@16	43.22D@24	44.53D@114	548microns	483microns	0.07D	0.76D
27	27	F	42.67D@47	44.45D@137	41.57D@115	42.21D@25	477microns	489microns	0.32D	0.44D
28	16	F	47.10D@24	49.78D@114	40.90D@165	41.09D@75	523microns	549microns	0.83D	0.29D
29	15	F	47.23D@38	50.78D@123	44.96D@14	48.97D@104	531microns	480microns	0.46D	0.94D
30	24	F	47.10D@24	49.78D@114	39.81D@09	40.05D@99	494microns	501microns	0.92D	0.21D
31	19	M	39.81D@09	40.05D@99	43.89D@172	44.72D@82	388microns	501microns	0.03D	0.27D
32	12	M	42.20D@07	43.05D@107	43.89D@172	44.72D@82	489microns	513microns	0.25D	0.3D
33	22	F	42.20D@17	43.05D@107	44.96D@14	48.97D@104	474microns	526microns	0.94D	0.31D
34	45	M	45.60D@08	47.22D@98	43.94D@179	46.54D@89	481microns	509microns	0.68D	0.23D
35	23	M	44.70D@08	47.14D@98	43.22D@24	44.53D@114	519microns	472microns	0.67D	0.3D
36	22	F	42.47D@05	42.98D@95	44.37D@165	48.64D@75	443microns	526microns	0.63D	0.76D