

# Pentacam – A Corneal Tomography System

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## Abstract

Investigative technology in the field of corneal refractive surgery has seen a rapid evolution in the last two decades. The shift from corneal topography system to corneal tomography analysis has not only improved the accuracy of corneal contour analysis but has also given an opportunity to explore various additional findings that are now considered extremely valuable in the diagnosis of forme-fruste keratoconus. This is of paramount importance in today's world considering the high flow of patients for refractive surgery and the need for precise screening for corneal ectasia in these cases prior to surgery. Pentacam (Oculus Wetzlar, Germany), based on Scheimpflug imaging, is the most commonly used corneal tomography system. It creates a 3-D imaging of the anterior segment and provides details of the anterior and posterior corneal contour, pachymetry, anterior chamber depth and pupil diameter. Recent advancement in the Pentacam software enables IOL power calculation as well phakic IOL simulation.

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## Introduction

The anterior segment imaging system has seen tremendous advancement in the last 20 years; however, Pentacam introduced in 2003 for commercial use is still one of the most commonly used instruments for corneal tomography. Pentacam is based on Scheimpflug imaging and falls into the category of elevation-based systems. The older machines were based on the Placido disc principle in which the data is solely dependent on the information acquired from the anterior surface of the cornea, therefore referred to as "corneal topography" system. On the other hand, Scheimpflug based devices provide actual information about both the anterior and posterior surface of cornea and hence are referred to as "corneal tomography" system. Scheimpflug based devices include - TMS-5 (Tomey, Nagoya, Japan), Pentacam (Oculus, Wetzlar, Germany), Sirius (CSO Florence, Italy), and Galilei (Ziemer, Port, Switzerland).<sup>1</sup> Sirius Scheimpflug analyser is based on Placido disc and a mono rotating Scheimpflug system for corneal photography whereas Galilei uses a dual rotating Scheimpflug camera along with a Placido disc system. With the increasing demand in today's world for refractive surgery, it is of paramount importance to quickly and accurately screen these cases for corneal ectasia prior to surgery.<sup>2</sup> A full pachymetric and keratometric map evaluation is a must. Also, considering the fact that posterior corneal contour is affected early in keratoconus, a true evaluation of the posterior surface plays an important role in screening. Pentacam captures 50 scans in two seconds and precisely estimates the details of anterior and posterior corneal contour, pachymetry, anterior chamber depth and pupil diameter. In addition, it provides the Belin-Ambrosio enhanced ectasia display that gives various parameters for the detection of forme-fruste keratoconus. All these features have made Pentacam an invaluable tool for anterior segment imaging especially in cases undergoing cornea based refractive surgery and cases of corneal ectasia. In the last few years its use has been extended to anterior chamber and

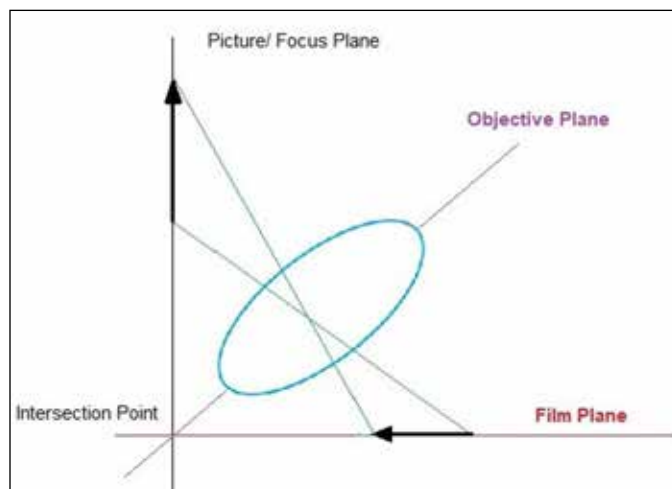


Figure 1: Principle of Scheimpflug Imaging system

angle evaluation in glaucoma, IOL power calculation as well as pre-operative phakic IOL simulation.<sup>1</sup>

## Principle

Pentacam uses a blue light (UV-free) of 475nm to illuminate the eye along with a rotating Scheimpflug camera which is a custom designed digital charge coupled device (CCD) with synchronous pixel sampling. The Scheimpflug camera is based on the Scheimpflug law that states "To get a higher depth of focus, move the three planes, provided that the picture plane, the objective plane and the film plane have to cut each other in one line or one point of intersection". (Figure 1,3) The machine has two cameras – a static camera in the center for detection of pupil size and for maintaining fixation of patient and another Scheimpflug camera mounted on a rotating wheel to capture the cornea and the anterior segment from limbus to limbus which provides a 3D view. The basic model of the Pentacam captures 50 scans in 2

seconds with 2760 true elevation points per scan and 138,000 true elevations points covering the entire surface of cornea i.e. from limbus to limbus. The slit images captured by the rotating camera are photographed from 0 to 180 degree angle to avoid shadows from the nose. The machine automatically corrects the small eye movements recorded thus making the examination procedure very comfortable, rapid and accurate. Along with that, the machine also corrects for the distortion caused by the camera optics, cornea or the lens. The images taken during the scan are digitalized and the data is transferred to the processor which provides a 3D virtual model of the anterior segment.

The scan is conducted in dark room and the patient is asked to fixate on the blue light in the centre of the machine. To decrease the operator – dependent variables, the machine has an automatic release mode which automatically determines the correct focus and alignment with the corneal apex and initiates the scan. The machine also has a quality check in the form of quality factor (QS) both for image analysis of anterior and posterior corneal surface and values of >95% are chosen for analysis.<sup>(4)</sup>

Three models of Pentacam are currently in use. The basic model measures the topography, elevation, corneal thickness and anterior chamber parameters. In addition, the Pentacam HR provides phakic IOL simulation and the Pentacam AXL also assesses the axial length for precise IOL power calculation.

**Parameters assessed**

The Pentacam gives detailed information about anterior segment parameters that includes the anterior as well as the posterior corneal contour and elevation, pachymetry, astigmatism, pupil size, anterior chamber depth, 3 D model of the anterior segment and others. The details visualized on Pentacam map are discussed in detail below-

**1. Patient information details**

The box on the extreme left top corner contains the information about the patient which includes the age, sex, the date of scan and the date of birth (Figure 2).

**2. Quality scan**

The quality of the scan is given by the QS (Quality specification) which tells us about the quality of the scan and it should be "OK". It is affected by eye movement and blinking. In case the result is "Data gaps" "Fix" or "Model" the scan should be repeated for accuracy.

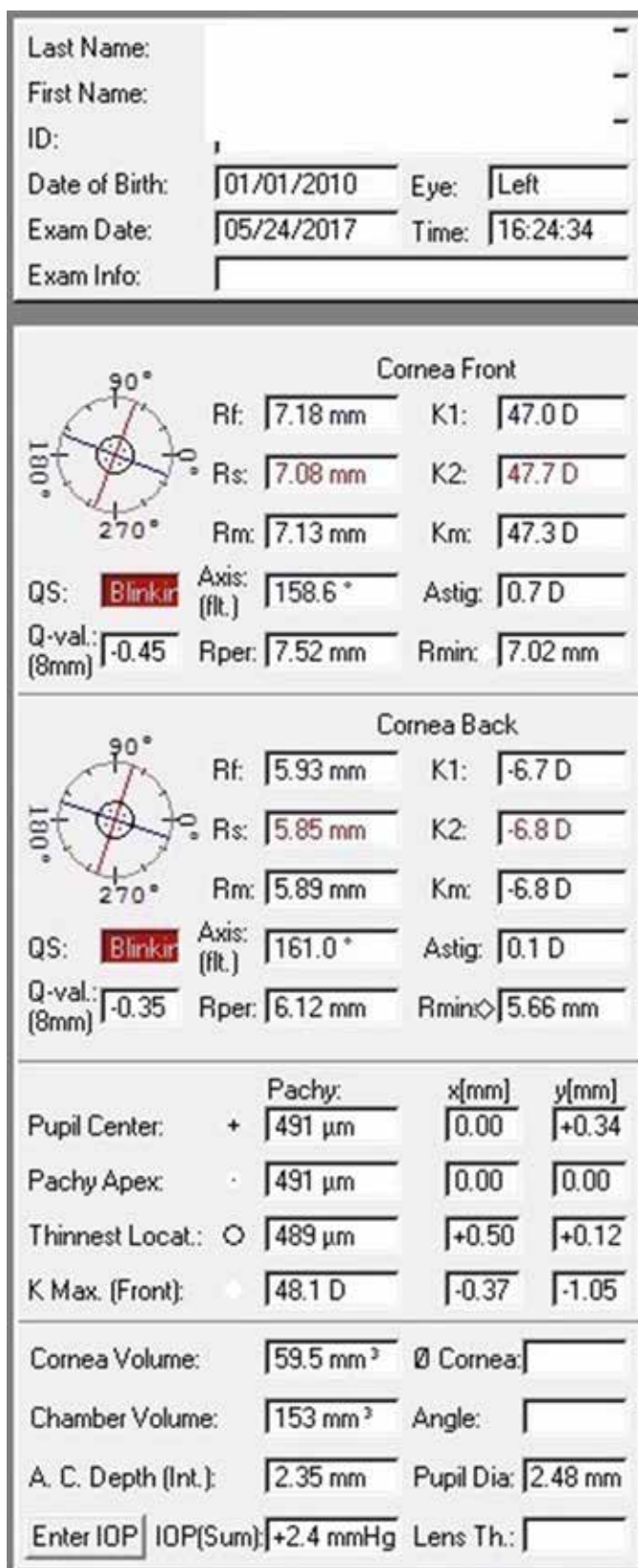
**3. Keratometry readings and Curvature Map**

**a. Q value**

The Q value tells us about the sphericity of the anterior surface of cornea. A value between 0 to -1 is considered normal and indicates a prolate shape (steep centre and flat periphery). A value >0 indicates an oblate cornea (flat centre and steep periphery) and a value < -1 indicates a hyperprolate cornea as seen in corneal ectasia.

**b. Keratometry values**

Keratometric value within the central 3mm zone in the



*Figure 2: Image showing patient information characteristics, summary of pachymetry and keratometry values. The corneal curvature is steep with K1 47D, K2 47.7D and Kmax 48.1D with associated corneal thinning (Thinnest location 489 μm)*

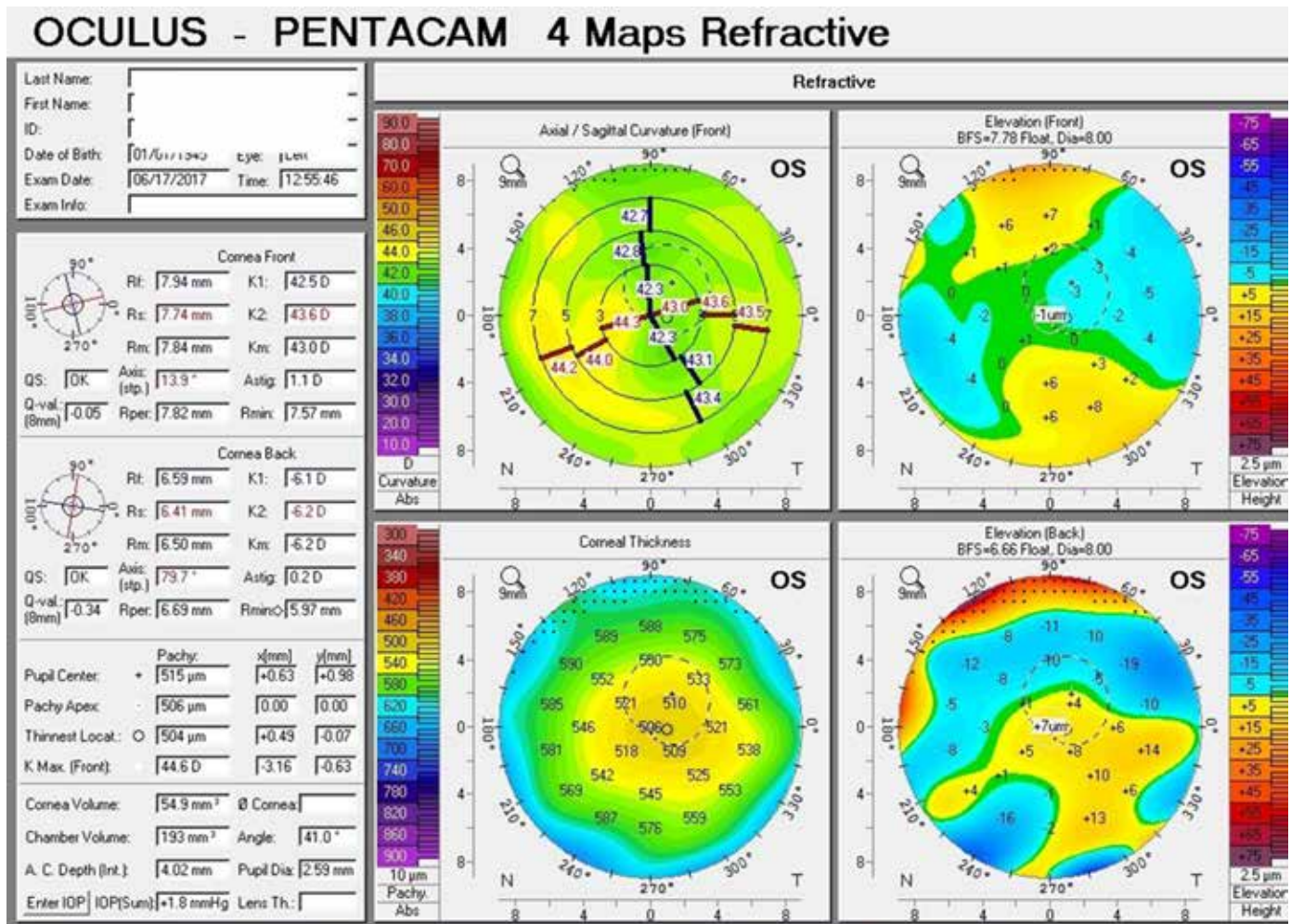


Figure 3: Pentacam quad-map showing the keratometry map, pachymetry map and anterior and posterior elevation maps which are within normal range.

flat meridian is K1 and in the steep meridian is K2. Km represents the mean keratometric reading of K1 and K2. The maximum keratometric reading of the anterior corneal surface is represented as Kmax (Figure 2).

**c. Anterior Curvature Map**

The curvature map shows keratometric power of the anterior corneal surface (central 8 mm) represented in a color-coded fashion (Figure 3,4). The hot colors (orange/red) indicate steep corneal contour while cool colors (blue/violet) represent flat corneal contour. A symmetric bow tie pattern is observed in the curvature map of cases with regular astigmatism.

**d. True Net Power Map**

It represents the cumulative keratometric power of the cornea taking into account both the anterior posterior corneal contour.

**4. Pachymetry indices and Corneal Thickness Map**

**a. Pachymetry values**

The pentacam shows three pachymetry reading that is the “Pachy apex” representing thickness of cornea at the apex/

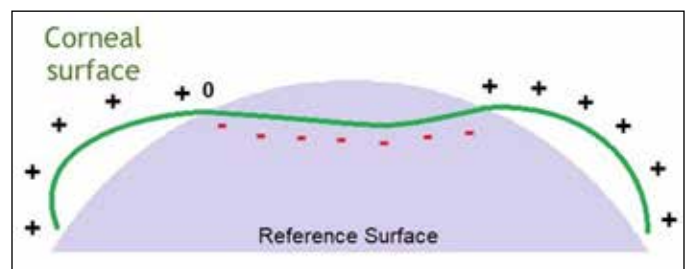
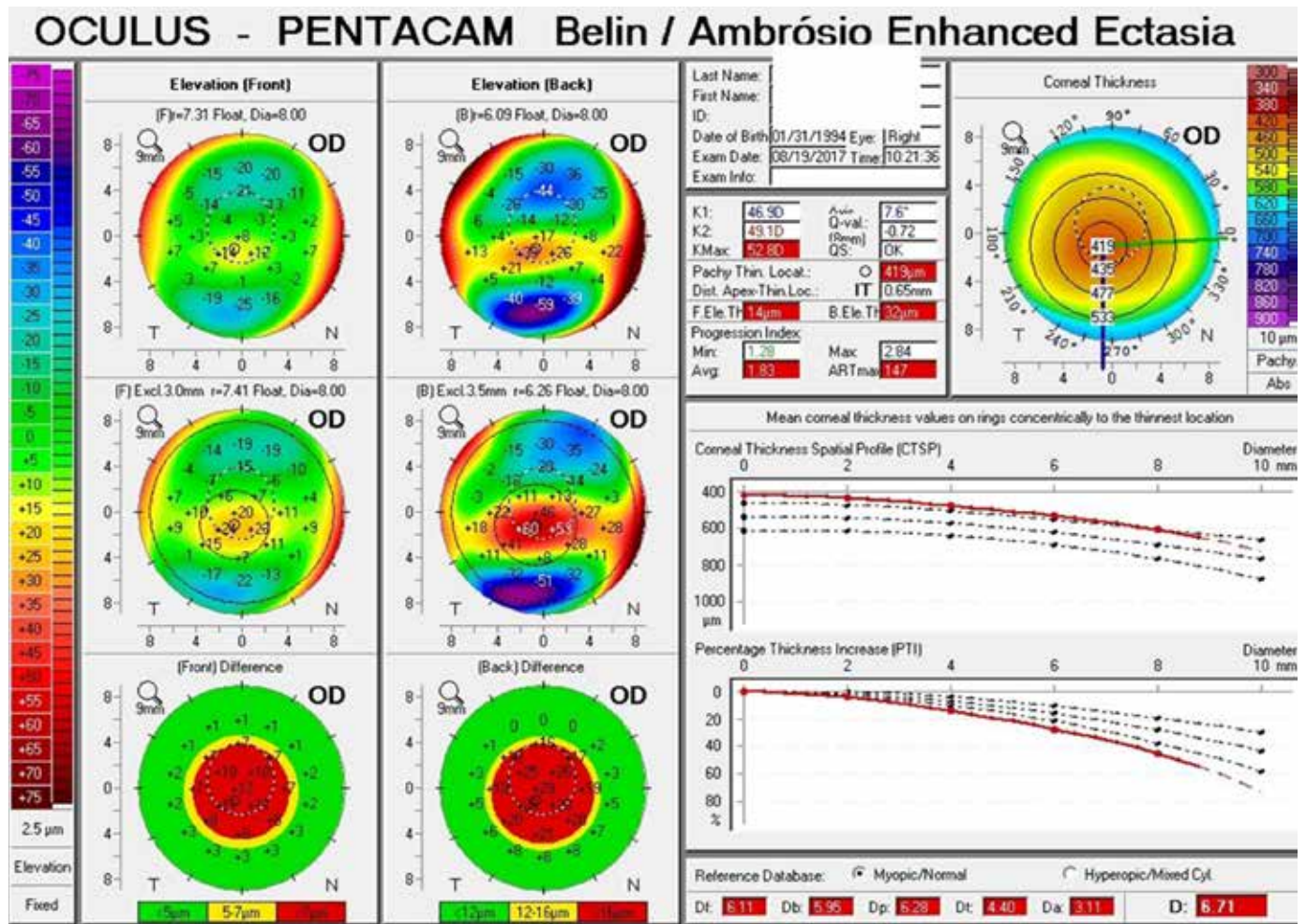


Figure 4: Schematic representation of the corneal elevation in reference to the best fit sphere

centre of cornea, “Pupil centre pachymetry” representing corneal thickness at the pupillary centre and “thinnest location (TL)” representing corneal thickness at the thinnest location. Pachy apex is considered as the reference point for measuring the displacement of all the other pachymetry indices. “X axis” and “Y axis” represents the horizontal and vertical meridian displacement respectively. The plus or minus sign signify the direction being above or below the reference point respectively.

**b. Pachymetry map**

In this map, the thickness at different points of the cornea (central 8 mm) is noted. The color corresponding to various



**Figure 5:** Belin ambrosio enhanced ectasia display showing hot colors in the elevation map (maximum posterior elevation - 60 µm) and difference map (maximum posterior elevation - 29 µm) along with deranged corneal thickness spatial profile (CTSP) and percentage thickness increase (PTI) as seen by the red line lying outside the two black dashed lines

thickness can be seen on the side panel of the chart. Cool colors represent thick cornea and hot colors represent corneal thinning. Normally, the pachymetry at the apex of the cornea is the thinnest point. A displacement of the thinnest point from the apex of cornea raises suspicion for corneal ectasia if it co-exists with corneal steepening.

**5. Elevation maps**

In this map, the elevation details of the measured corneal surface are compared to a reference surface which maybe a best fit sphere (BFS) or a best fit toric ellipsoid (BFTE). Points above the reference sphere are considered elevations and expressed in plus values (hot colors), and those below the reference sphere are considered depressions and expressed in minus values (cool colors). Separate anterior and posterior elevation maps are present. It is useful in early detection of cases with corneal ectasia.

**6. Pupil Diameter**

The Pentacam gives an accurate assessment of the mesopic pupil diameter (PD) which is essential to screen in patients planned for refractive surgery. Large mesopic PD (>5 mm) results in glare and halos following surgery.

**7. Anterior chamber analyzer**

The Pentacam creates a 3D model of the eye and estimates parameters like the anterior chamber angle and anterior chamber depth (endothelium to the anterior lens capsule) which is valuable in assessing cases of glaucoma. It also gives the cornea corrected intra-ocular pressure value. An additional software for densitometry assessment gives results for corneal and lens densitometry.

**8. Belin Ambrosio Enhanced Ectasia Display (BAD map)**

This map is based on the concept of the Enhanced best fit sphere which is calculated after taking into consideration the keratometric readings of the patient’s cornea. This helps to highlight subtle corneal abnormalities which maybe missed on the elevation map based on the best fit sphere (Figure 5). The elevation maps are calculated according to the best fit sphere and also the enhanced best fit sphere model in the Belin Ambrosio Enhanced Ectasia display.<sup>5</sup> A difference map between the two is also shown in this map. Additional graphs seen in the BAD map include.

**a. Corneal thickness spatial profile (CTSP)**

The graph represents the average progression of the corneal

thickness from the TL to the corneal periphery. The graph is plotted using red dots and it should lie within the three black dotted lines plotted for reference with the average being 0.8-1.1. Any sudden slope or rise within the 6 mm zone is considered abnormal.

**b. Percentage Thickness Increase (PTI)**

The graph represents the percentage plot of the above graph. Any sudden slope or rise within the 6mm zone is considered abnormal.

**c. D value**

It consists of 5 parameters including Df for the front surface, Db for the back surface, Dp for pachymetric progression, Dt for the thinnest point and Dy for thinnest point displacement. Each individual parameter and their final D number are normalized to their mean value and reported as standard deviation from the mean (D value).

The parameter is indicated in white box (normal) <1.6SD, yellow box (suspicious) >1.6 SD or red box (abnormal) >2.6 SD. However, one should also correlate the age of the patient with the D value as the threshold for suspicion is higher in older age group when compared to young individuals

**Clinical Applications**

**1. Screening for corneal ectatic disorders**

Keratoconus being the most common corneal ectasia can be easily missed on normal slit lamp examination and manual keratometry which only evaluates the central 3mm of cornea. Various criteria have been set to diagnose keratoconus or

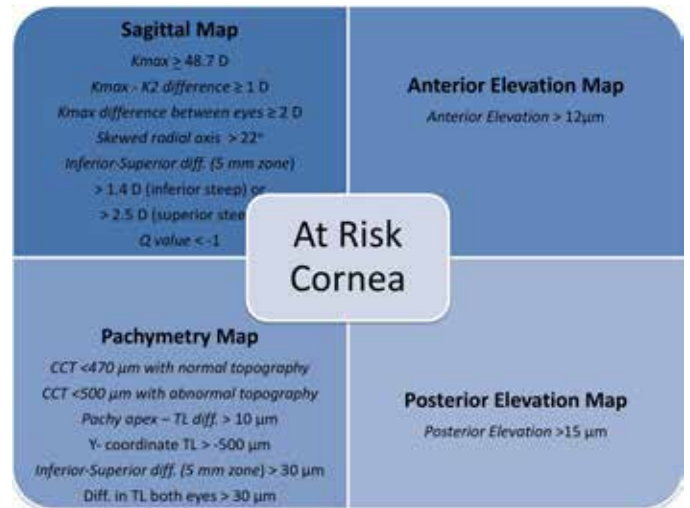


Figure 6: Red flag signs for corneal ectasia on Pentacam maps

forme fruste keratoconus with the help of the maps described above. (Figure 6,7)

**2. Corneal ectasia monitoring and treatment**

With the help of regular tomography maps of the patient, the disease progression and the response to treatment can be monitored. Early changes in the progression maps help us to plan timely intervention

**3. Refractive surgery screening**

It improves the precision of screening for FFKC and corneal

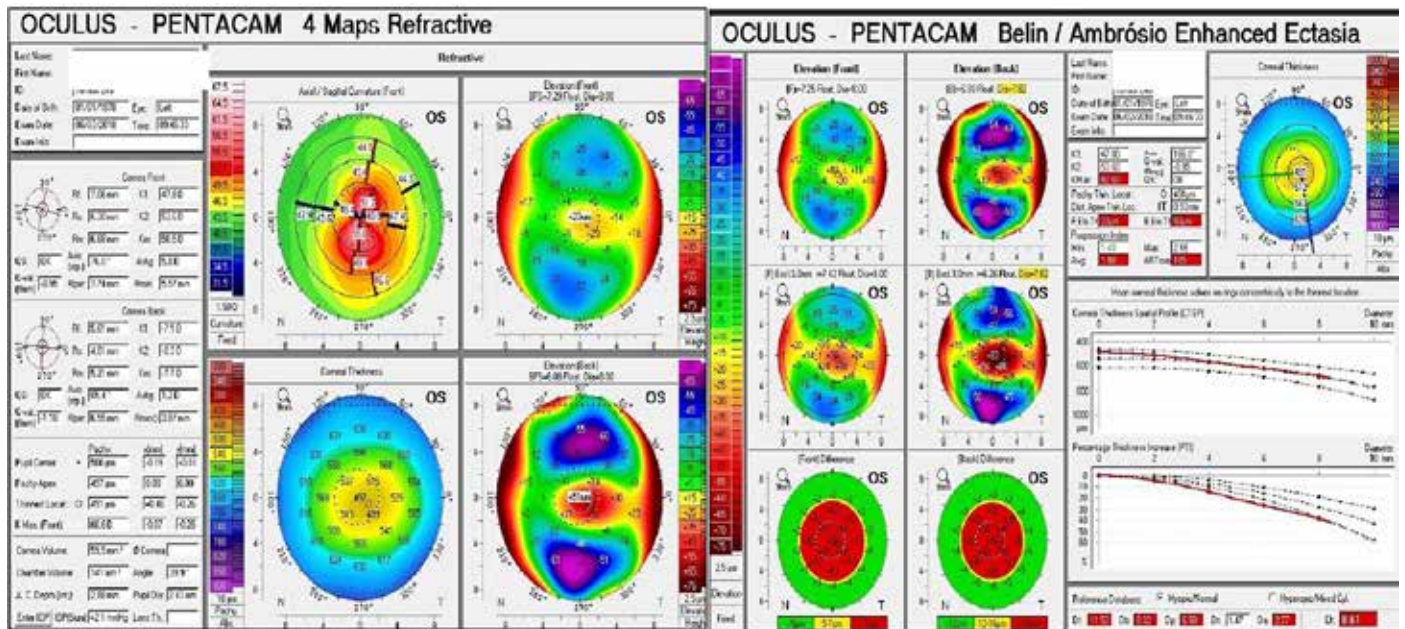


Figure 7: Pentacam map of a keratoconus patient showing (left) an asymmetric bow tie pattern (inferior steepening) on the axial curvature map with corresponding corneal thinning; thinnest location of 491 µm with 0.46 mm and 0.26 mm displacement on the x and y axis respectively; increased anterior and posterior elevation (maximum anterior elevation of 23 µm & maximum posterior elevation of 51 µm) at the location of maximum steepening (right) Belin-ambrosio enhanced ectasia display map of the same patient showing hot colors in the elevation maps and difference map along with abnormal percentage thickness increase graph (steep dip from the 2 mm zone) and D value of 8.6.

ectasia prior to refractive surgery. It also helps in appropriate planning and careful selection of the type of refractive surgery that would be suitable for the patient.

#### 4. Phakic IOL implantation

The 3D chamber analyzer is useful in pre-operative assessment of patients planned for phakic IOL implantation. It provides precise value for anterior chamber depth that is crucial for planning of this procedure.

#### 5. Lens densitometry

The densitometry software provides a grading of the nuclear cataract by taking into account the volume and density of the lens. It also helps in diagnosing cases of capsular bag distension syndrome and posterior capsule opacification.

#### 6. Improved IOL calculations

Taking into consideration the actual keratometry reading provided by Pentacam, a precise IOL power calculation can be done as compared to the previous keratometers which take into account only the anterior surface of the cornea

#### 7. Zernike analysis and corneal Wave front

It determines the higher-order aberrations (HOA) of the cornea. It helps in planning the type of IOL (aspheric or those with spherical aberration) to be implanted in patients undergoing cataract surgery based on the Q value of the cornea. Also, patients with high HOA can be planned for wavefront guided LASIK

#### 8. Glaucoma evaluation

The 3D chamber analyzer is also useful for glaucoma patients. It gives values for anterior chamber angle and anterior chamber depth which are important parameters for angle closure glaucoma patients

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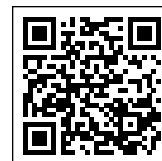
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