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Design and Construction of a Corneal Topography Examination Device

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Abstract:

In this work, a corneal topographic study system was designed and built based on the principle of the Placido disk, which depends on capturing the reflection image of the concentric rings separated by fixed distances and illuminated by a white photodiode on the tear layer on the surface of the cornea.

The built device was calibrated using three glass balls of different radii by calculating the average distances between the reflected rings from the three balls, to find a relationship between the distance between the reflected rings and the radius of curvature to be used in measuring the radius of curvature of the eye for multiple points.

Photographs of the reflection of the illuminated pattern were taken from the eyes of a patients for the purpose of analysis. By means of a gradient of gray level and using the ImageJ program, and matching the curves, the positions of the peaks were determined for eight radial axes from the center of the pupil, with separating of 45 degrees.

The radius of curvature of the cornea was calculated at several points using the interstitial distances, and then the average was found for three regions within radii of 3, 5, and 7 mm. The keratometric values of these points were calculated, and then the color distribution of these values was drawn, which is represented by the curvature map and the keratometric map, using Origin software.

The device showed the possibility of analyzing the color distribution of the maps by consulting a specialist doctor to determine the type of refractive error that the patient suffers from, which was determined as asymmetrical astigmatism due to a slight deformity in the cornea.

Introduction

Imaging techniques for assessing the structure and function of the cornea and anterior segment are crucial for diagnosing and treating a wide variety of ocular diseases. There is a huge variety of diagnostic testing available to ophthalmologists, and learning how to interpret these tests can seem daunting. For those beginning training in ophthalmology, the utilization of common diagnostic tests provides quicker and more accurate diagnosis and management of corneal diseases [3].

Corneal Topography

Corneal topography is the study of the shape of the corneal surface. Traditionally, such measurements were limited to the near-spherical central portion of the anterior corneal surface. With the advent of corneal refractive procedures, the necessity to study the more peripheral parts of the cornea and to understand better the optics of both the anterior and posterior corneal surfaces has spawned a number of new devices that allow the clinician to better understand corneal shape, power, and optical performance [4].

Evolution of Corneal Topography (Keratoscopy)

It is the evaluation of the corneal surface using circular mires reflected from its surface. The earliest device designed to perform this function was the PLACIDO’S DISC, developed by Antonio Placido.

It consists of equally spaced alternating black and white rings with aholein the centre too bserve the patient’s cornea. The central opening houses a convex lens for magnification and to aid the examiner’s accommodation. Figure 2 .1 shows a Placido’sdisc–based systems and examples of images obtained from the reflection of the mires from the cornea.

Figure 2 .1: Placido'sDisc–Based Keratometry Systems

Keratoscopes are devices with a self-illuminated set of concentric rings, like the Placido disc, and documentation of the obtained mire reflection can be done using a camera (Photokeratoscopy) or a videocamera (Videokeratoscopy). With advances in computing power, the addition of computers to the above devices has increased the amount of information that can be obtained and quantified from the reflected images. Apart from the qualitative assessment that is possible from the mire reflections, the use of algorithms to analyze the images results in large amounts of quantitative data that can be obtained virtually in real-time, with the powerful computers available today [5].

Working Principle of Placido based devices

These work on the Reflection principle. The anterior surface of the cornea acts like a convex mirror and hence the size of the image formed by it is determined by its curvature. A steeply curved cornea will produce a smaller image, while a flatter cornea will produce a larger image – of the same object positioned at the same distance from the cornea. These devices thus, measure the slope of the cornea and compute the curvature. These work true to the principle of the Placido disc. They have different projection devices that use lighted circular rings of varying sizes and numbers. These rings are reflected by the convex patient cornea and through an opening in the center of the target, the images are obtained using an acquisition camera [6].

The images are digitized, after allowing operator verification, and proprietary algorithms are used to determine the radius of curvature of the innermost ring. Once this is determined, the distance of the next reflected ring from the first ring is used to determine the curvature of this ring an so on – until the most peripheral ring is reached.

Usually, these values are determined for a finite number of points on the circle represented by each ring. Thus, the cornea between rings is not imaged and there is no actual data for these points. Thus, the apex of the cornea which is inside the innermost ring, is also not visualized or measured. Since reflection of images is a tear film based property of the cornea, in eyes which have irregularities of the corneal surface – or other tear film problems, distortion of the reflected images results in inaccurate estimation of corneal curvature [7].

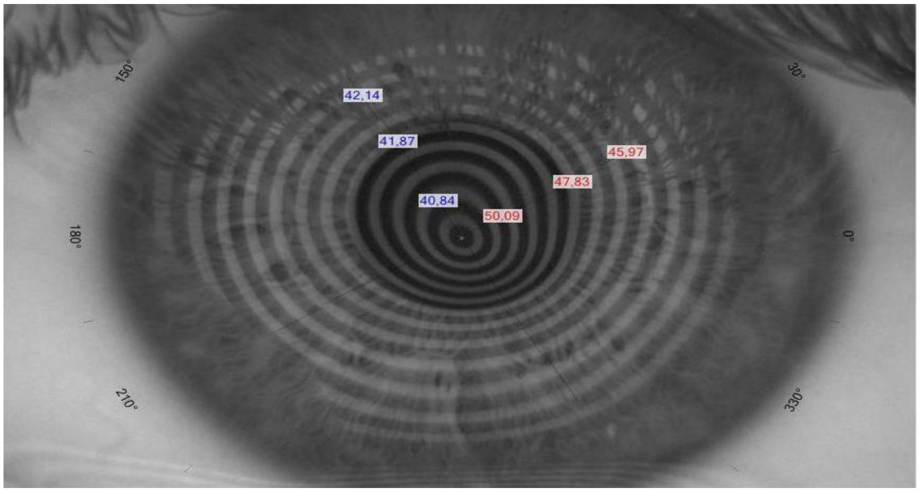


Figure 2 .2: Reflected miresfrom a cornea

Once the curvature of the points is determined, the corneal dioptric power at that point is determined using the formula

$$Dioptric\ power\ of\ the\ Cornea\ = \frac{refractive\ index\ of\ cornea - refractive\ index\ of\ air}{radius\ of\ curvature\ in\ meters}$$

However, since the measured radius of curvature is of the anterior corneal surface, the conversion provides the power of the anterior corneal surface. Since there is negative refraction when light passes into the eye, through the posterior corneal surface – this is accounted for in most keratometers, by using an effective corneal refractive index instead of the true refractive index. Although this effective [8]

Keratoconus

Keratoconus is a degenerative non-inflammatory disease of the cornea. It presents generally at puberty with progressive corneal steepening & thinning, most typically inferior to the center of the cornea. Keratoconus is characterized by progressive Myopia, both regular and irregular astigmatism in mild cases and vision compromising ectasia in advanced disease. It is usually bilateral and asymmetrical. The incidence of keratoconus is 1 in 2000. Patients often present with complaints of distorted, blurred vision, glare, light sensitivity and history of frequent change of glasses [9].

Keratometer

In general, either manual or automated keratometer have been used for taking the keratometric readings (K readings) in the clinic. The keratometer projects a ring light onto the corneal surface. The image created by the reflection of the ring illumination from the tear film on the corneal surface is the first Purkinje-Sanson image and is called the mire.

The radii of the corneal curvature and the axis of astigmatism are determined by analyzing the size and toricity of the mire while keeping the working distance constant and the eye fixed. The keratometer measures only the corneal radii of the front surface and estimates the total corneal power of the anterior and posterior surfaces, not with the true refractive index of the corneal stroma (1.376), but with the keratometric index (1.3375) based on the assumption that there is a constant ratio between the anterior and posterior corneal curvature. This is called as the Gullstrand ratio in the Gullstrand exact schematic eye [10].

The keratometer uses a single mire which provides information on the values at the paracentral zone only (about 3 mm in diameter), while a corneal topographer covers a large area of the cornea with a Placido disc that comprises multiple coaxial ring illuminations. Corneal topography provides a color-coded topographic map based on the power across an extensive area of the cornea and topographic indices based on the mires. Corneal topography enables us to diagnose corneal shape abnormalities and to evaluate irregular astigmatism or higher-order aberrations (HOAs) qualitatively by the visual inspection of a color-coded map and quantitatively by the topographic indices.

The advantage of a Placido-based corneal topographer is that it uses the same principle as a keratometer for measurement; simulated K readings can be shown as the compatible index of K readings although these two indices are not always interchangeable. Placido-based corneal topography obtains the image created at the pre-corneal tear film quickly in a single shot, which contributes to the good reproducibility of the data. However, caution should be heeded with the errors associated with changes in the tear film such as dry eye and prior contact examinations [11].

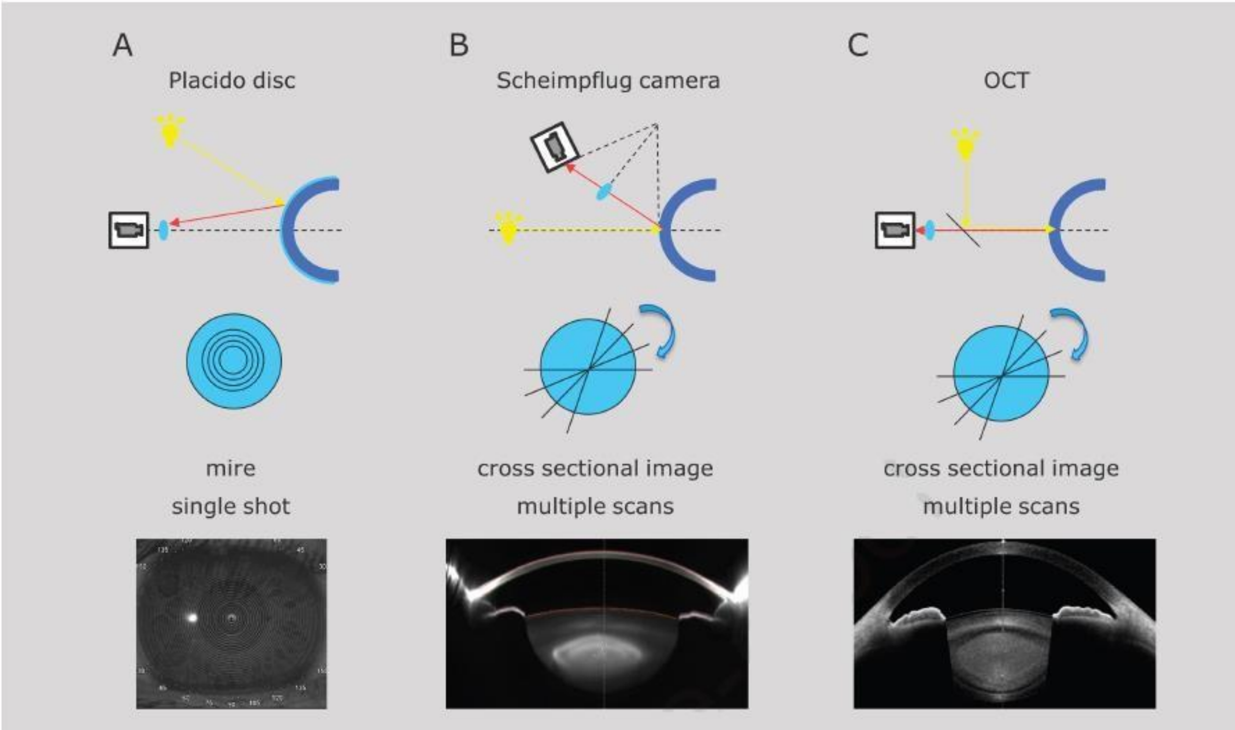


Figure 2 .3: the three types of corneal topography devices

Computerized corneal topography

It is a method for accurately assessing the curvature of the cornea and its ability to adjust the focus of the images, which exploits the computational capabilities of the computer.

The device is able to examine with great accuracy, and instantly, the entire curvature of the anterior transparent surface of the eye.

Corneal topography is a very important tool for following the progression of diseases that alter the curvature of the cornea (eg keratoconus), for the differential diagnosis of certain diseases, for pre- and post-operative evaluation in refractive surgery, and for the careful selection of the lens to be used during cataract surgery.

- It is very useful for simulating contact lens application on the eye.
- The properties of convex mirrors are used to make measurements.
- The cornea has a mirror-like surface.

Part of the light that reaches it is concentrated inside the eye, while another part is reflected in a manner similar to what can be seen in mirrors installed at some intersections to allow panoramic vision.

If you look closely into the eyes of someone close to you, you can see your very own little self-reflected in them.

Convex mirrors reduce the dimensions of the reflected images, to a more noticeable extent, the greater the curvature of the surface of reflection (for this reason, mirrors at road junctions provide a panoramic view).

Most topographers (CSO, Optikon, Tomey) use corneal reflection for a given image, consisting of a series of concentric luminous rings projected from a small dome (at first the rings were drawn on a flat disk with an observation hole called the "Placido disk" after its inventor), precisely at a predetermined distance.

A corneal topography computer can use a series of formulas, and perform many calculations, to measure the zoom out of the reflected circles of light, and evaluate the curvature or elevation of each point of the cornea.

With further calculations, it allows predicting how these curvatures affect the focus of light rays in the eye, also taking into account the dimensions and position of the pupil to the optical axis.

Mapping out Corneal Topography

Corneal topography is exceptionally useful for examining characteristics of the cornea such as shape, curvature, power and thickness. It is also an essential tool for the contact lens specialist [12].

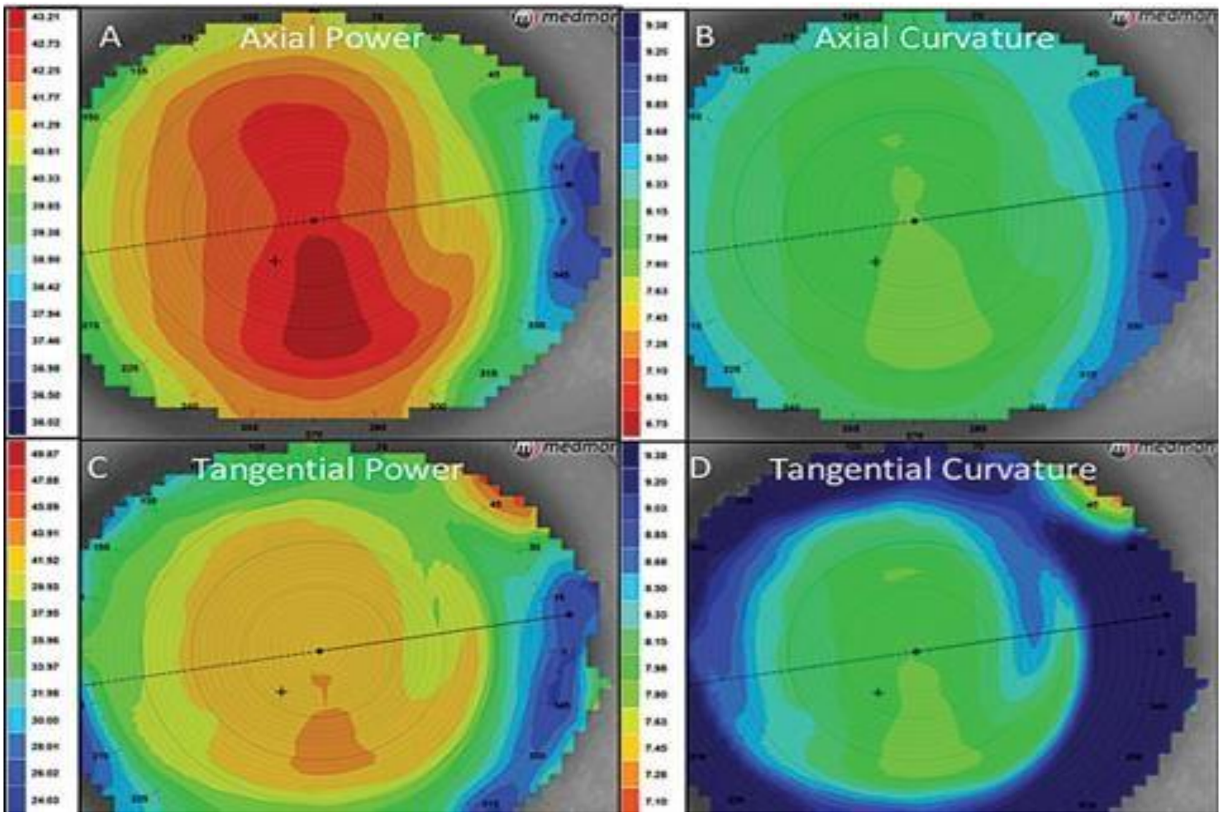


Figure 2 .4: The four basic power maps of corneal topography. ODs can view the axial map (A, B) and tangential map (C, D) as power or curvature.

Placido Disc Topography

After projecting a concentric annular light source onto the corneal surface, placido disc reflection systems capture the reflected light so their software can measure curvature, irregularities, foreign bodies, tear film nuances and other characteristics of the anterior cornea. These systems are highly dependent on the tear film, which is the part of the ocular surface that is actually reflecting light. This allows for a noninvasive measure of tear film quality, but it can also hinder accuracy when measuring corneal power and shape.

Placido disc systems can be categorized as either small-cone or large-cone systems. Small cones collect more data points and are ultimately more accurate, but large cones are easier to manipulate and data collection can be easier. Some examples of small-cone placido disc systems include the E300 (Medmont), Keratron (Optikon), Keratron Scout (Optikon) and Keratron Piccolo (Optikon), while large-cone system examples include the Keratograph (Oculus), Atlas (Zeiss) and ReSeeVit (Veatch Ophthalmic Instruments) [13].

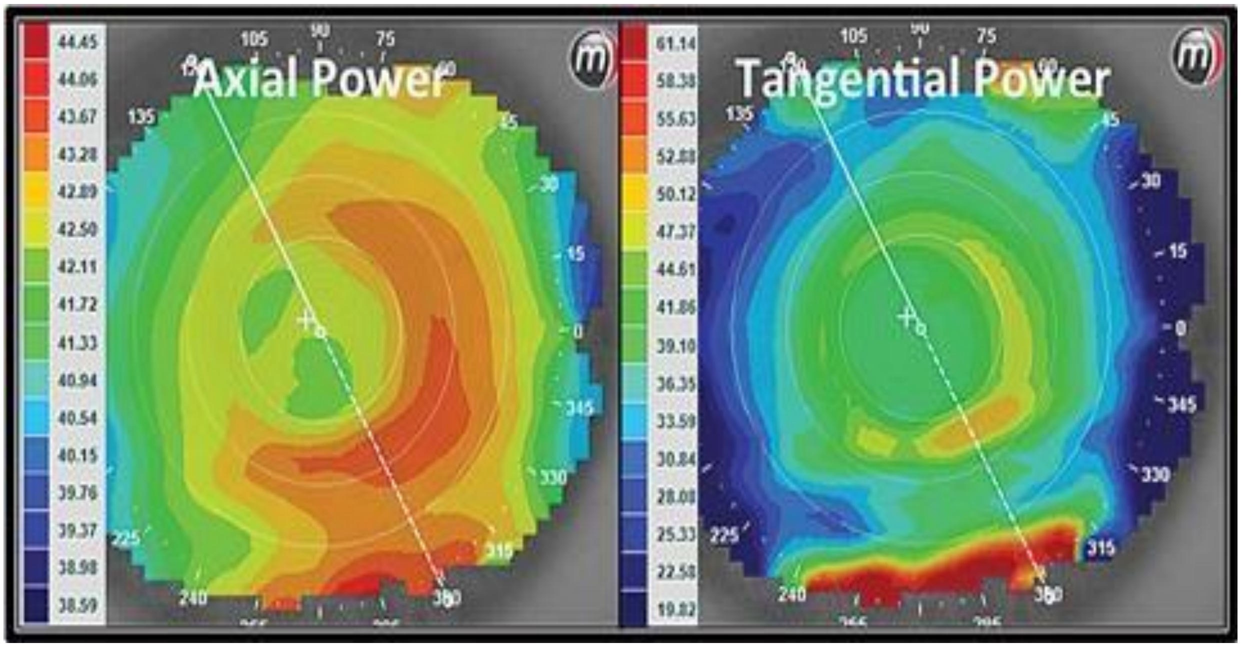


Figure 2 .5: Axial and tangential power maps show an eye wearing a +2.50 center distance soft multifocal lens design. Click image to enlarge.

Scheimpflug and Scanning-Slit Topography

The primary difference in output data from a placido disc system when compared with a Scheimpflug or scanning-slit topography system is that the latter two provide information about the posterior cornea. Rotating Scheimpflug cameras, such as the Pentacam (Oculus), use off-axis light to capture precise measurements of the anterior and posterior surfaces of the cornea, allowing the system to calculate global pachymetry and allow characteristics such as corneal swelling to be monitored during contact lens wear.[2] Scanning-slit topographers, such as the Orbscan (Bausch + Lomb), project two vertical scans through 40 optical slits at fixed angles to analyze the curvatures at the anterior and posterior corneal surface, also allowing the system to gather posterior data, including thickness (Figure 2 .6) [14].

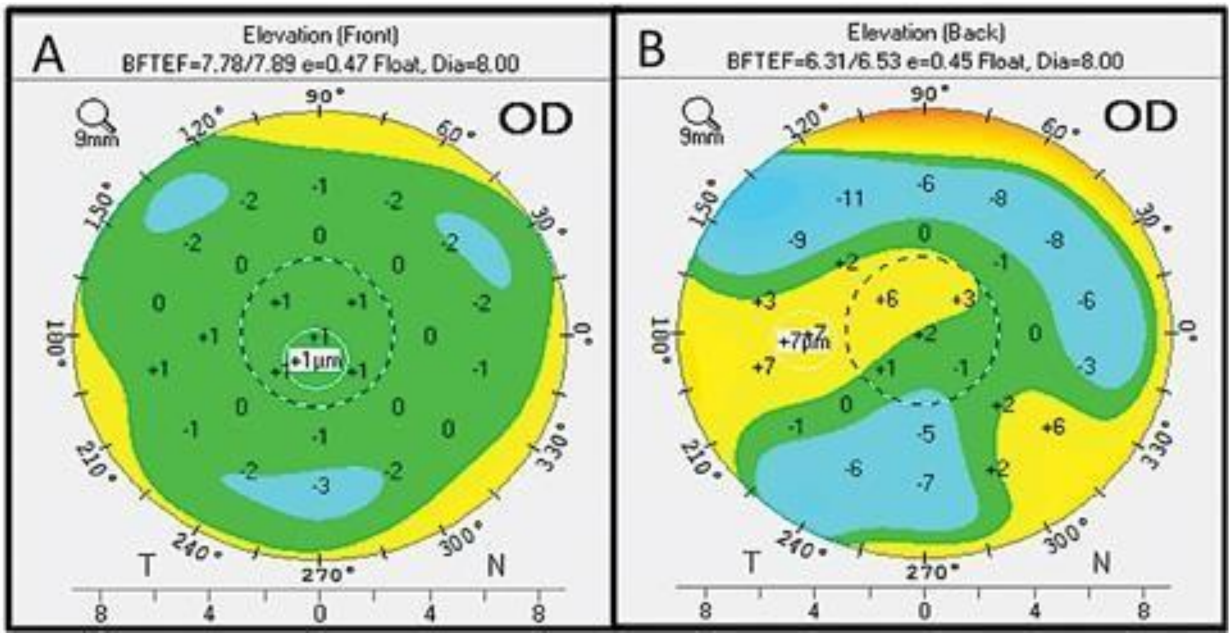


Figure 2 .6: An example of an elevation map from the Pentacam. Click image to enlarge.

Corneal topographers collect tens of thousands of data points from the corneal surface. From these data points, power, shape and other characteristics of the cornea can be calculated. Display options for this information depend on what information is needed, which makes a thorough understanding of the different corneal topography map types important. While there are dozens of different display options in the various topography instruments, the following are the most applicable to contact lens care.

Axial Display Map

The most traditional way to view a topography image is with the axial display map (*Figure 1*). One positive of this map is that it is the best way to get a quick overview of the corneal power. It can be also misleading, however, because it averages the data to create a “smooth” map, making it less accurate than other power maps (i.e., tangential). Central data is more accurate than peripheral data on the axial map because the averaging algorithms in the software assume a spherical surface and the cornea becomes more aspheric in the periphery. Depending on which area of the cornea is being evaluated, the averaging feature of the axial map could be a major limitation. For example, if central data is of greatest importance, then the map will be relatively accurate, but if a specific power map of the periphery is guiding a choice about a contact lens fit, the map may not provide the accuracy you need.

Axial maps are ideal for base curve selection of a corneal or soft contact lens because the average of the central curvature is portrayed. For specific information about the corneal shape and power, other displays will be more helpful [15].

Tangential Display Map

The most sensitive of the power maps are tangential display maps, and as such, they measure power and curvature at individual points on the cornea the most accurately. Often, a lens fitter must be aware of the precise changes to the corneal curvature when making clinical decisions. Some indications of corneal topography will benefit from use of the tangential map display more than others. For example, tangential maps may be beneficial in orthokeratology (ortho-k), especially when evaluating the shape of the peripheral cornea, as this display provides the most accurate peripheral data.[3]

Additionally, evaluating a contact lens power while it is on the eye can be done using the tangential display map, especially when a patient is wearing a multifocal lens and the positioning of the optics is important (*Figure 2*). The display will show the power of the contact lens over the cornea, so that an examiner can accurately observe the positioning of the lens optics or to get a better clinical picture of what optics are on the surface of the eye when the patient is wearing a contact lens. The tangential display is also the most sensitive to changes in corneal curvature caused by distortion or warpage of the cornea from contact lens wear [15].

Elevation Display Map

The go-to option for conveying the true shape of the cornea is the elevation display map. It is important to note that placido disc systems use complicated algorithms to calculate the corneal elevation, while Scheimpflug systems measure the elevation directly, so the latter system may give the most accurate data.[4] Regardless, both systems output elevationinreferencetoa“best-fitsphere,” which is calculated and extrapolated through the cornea. The systems then calculate areas of relative elevation or depression based on the deviation from the best-fit sphere, and the deviation values are displayed in microns (Figure 2 .7). In placido disc systems, only the anterior surface is measured, while Scheimpflug systems measure both the anterior and posterior elevations. Clinically, both technologies are adequate for contact-lens-related use.

This elevation display map is important when first determining the best lens design to fit on an irregular cornea, specifically when deciding between a corneal or scleral gas permeable (GP) lens. Corneal GP lenses rest on the corneal surface, so the anterior shape of the cornea is important in predicting their success. The elevation display map shows the shape of the anterior surface, which is important because as the irregularities of the cornea become greater, the surface is less likely to be symmetric, making it difficult to fit a mostly symmetrical lens on top of the surface.

Based upon clinical experience, a difference in corneal elevation greater than approximately 325µm (between the highest peak and lowest point of elevation) will lead to limited success with corneal GP fit stability. GP lenses fit onto a cornea with these levels of elevation difference will rock on the eye, fall out of place intermittently and often cause discomfort and visual instability in wearers.

Individuals with this amount of elevation variation will likely need a scleral lens, which is less sensitive to corneal elevation differences because they vault the cornea.

The elevation display map is also useful in ortho-k management. Evaluating this map at baseline will allow practitioners to determine if the corneal shape is regular enough to support an ortho-k lens. More specifically, it will help them decide whether to use a dual-axis or single-axis lens. A patient with astigmatism will have differences in elevation between the two major meridians. If this difference in elevation is greater than about 15µm between the meridians, a dualaxis option will be needed to ensure the same depth remains evenly distanced from the cornea throughout the entire return zone. In ortho-k, this is essential to ensure even distribution of the displaced cells [15].

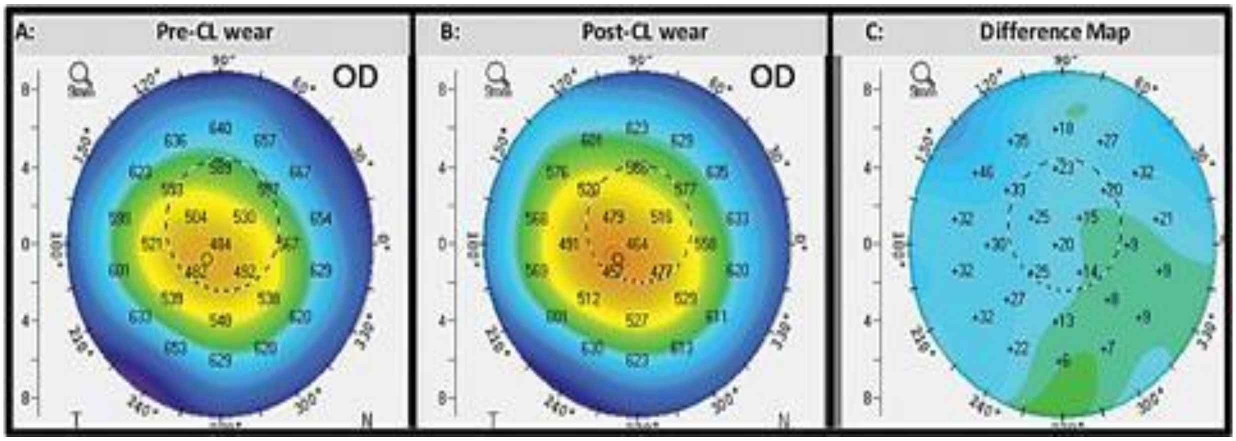


Figure 2 .7: Comparative display shows the corneal thickness displays of the same eye before (A) and after (B) initiating contact lens wear. The difference map (C) calculates the change in corneal thickness. Click image to enlarge

Corneal Thickness Display Map

Pachymetric capabilities are only available in Scheimpflug cameras and scanning-slit topographers, since these instruments measure posterior as well as anterior surface characteristics. This display can be used to stage diseases (i.e., keratoconus), but in active contact lens wear, the primary use of this display is to monitor corneal thickness changes due to contact lens-related hypoxia.

Evaluating corneal thickness changes during contact lens wear is important for scleral lens wearers, as they may be more prone to hypoxic complications. The corneal thickness display map is helpful for these patients (*Figure 4*).[5-8]

The corneal thickness display map can also be beneficial in ortho-k management, allowing practitioners to monitor corneal thickness changes as tissue is displaced from central to peripheral. This is a great supplement to the tangential and elevation displays and can be valuable when making determinations about lens fitting. When ortho-k lenses for myopia are worn, tissue is moved from the central cornea to the periphery. As a result, the central cornea will become thinner and the peripheral cornea thicker. The sensitive global pachymetry measurements can show if there is asymmetry in the movement of tissue centrally to peripherally [16].

Tear Break-up Display

Among the most novel options on modern topography instruments for contact lens management are tear break-up displays Figure 2 .8.

Noninvasive tear break-up scores can be measured prior to initiating contact lens wear to gauge the quality of the natural tear film and see how it is affected by contact lens wear.[9] A measurement is taken prior to lens wear and then compared to the subsequent measures to see how tear film quality is objectively affected in lens wearers with and without the lens in place.

Tear break-up displays can also be used when taking topography over the top of a contact lens. The surface wettability of the lens can be indirectly evaluated using this display, and a quantitative monitoring over wear time [16].

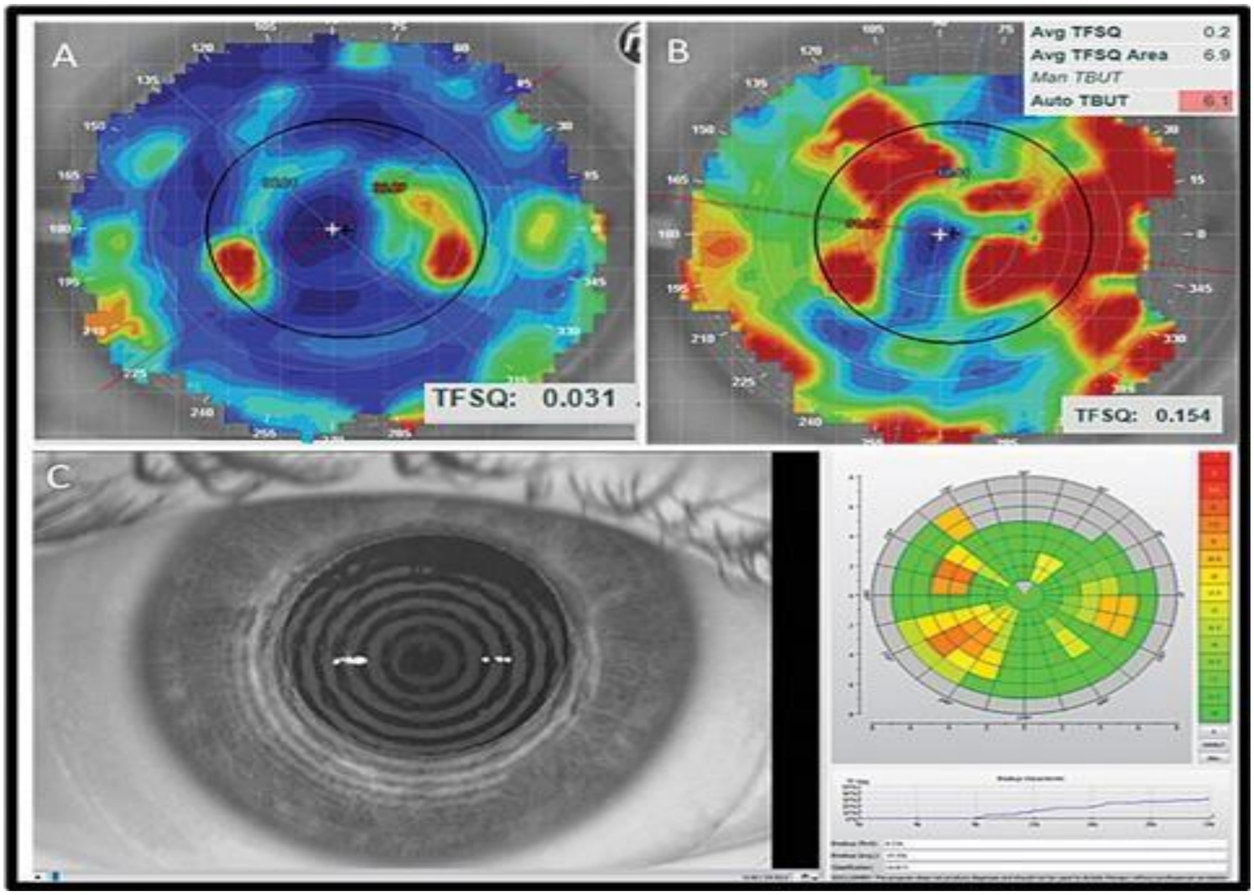


Figure 2 .8: A few examples of noninvasive tear breakup assessments. The top panel shows the tear film quality score display from an E300. The bottom panel is a similar assessment using the keratography.

Additional Features

Beyond the various displays that can be applied to contact lens management, many modern topography systems have additional features that are applicable to contact lens care.

Contact lens fitting software allows practitioners to simulate a contact lens on the ocular surface and empirically order lenses that incorporate the entire shape of the cornea, including peripheral eccentricities, to provide a more customized contact lens fit. These programs have been shown to be effective at predicting the fit of a corneal keratoconus lens.

Design-specific software, in which practitioners can upload topography images to simulate lens fits prior to ordering, is also available through lens manufacturers. These programs are most useful with corneal GP fitting, as the base curves of irregular corneas are not as predictive of scleral fitting [17].

The OxiMap feature of the Keratograph calculates the Dk profile of specific contact lenses, and since the Dk is usually reported for powers of -3.00D only, this is useful information when practitioners want to know the specific Dk in all areas of the lens. This feature also aids practitioners in understanding the Dk profile of high-power lenses, or when fitting patients who are prone to hypoxic complications.

Many topography systems feature photography. These instruments are capable of snapping photographs of the iris and pupil behind the cornea in addition to the cornea. Practitioners can use these photographs to measure pupil size and centration. When fitting bifocal lenses for presbyopia and myopia control, this feature allows practitioners to match pupils to the optics of the lens, maximizing the understanding of optic placement for each individual. From this, practitioners can also calculate horizontal visible iris diameter and glean information about eyelid placement in relation to the cornea and pupil.

Meibography can be done using some topography systems to show changes in meibomian gland (MG) quality throughout contact lens wear. There is some evidence that the amount of MG atrophy may be greater in chronic contact lens wearers, and patients with MG atrophy may experience reduced comfort, so a system to monitor MG quality could help practitioners confirm a correlation. Meibography images also allow for subjective MG evaluation, and enhancements of the resulting images can reveal the location of tortuosity and atrophy.

Aberrometry can also be used on many topography systems to troubleshoot visual dissatisfaction with contact lenses. If a patient has non-specific visual complaints, taking these measurements with and without contact lenses in place can help determine which modality is most appropriate. If an excess amount of aberration exists prior to contact lens wear, the patient will be best suited for a rigid modality. Aberrometry taken over a contact lens will show how well a lens is able to correct higher-order aberrations.

Corneal topography is an established and important technology for measuring the shape and power of the cornea. It allows practitioners not only to fit contact lenses to match the power and shape of the cornea, but it also helps them to evaluate intricacies of the contact lens relationship with the ocular surface. As these systems continue to develop modules to better evaluate corneal surfaces and tear film, practitioners can provide more specific and advanced management to their contact lens patients [18].

Experimental Work and Procedure

Introduction

The present chapter described the experimental setup, procedure, and the technique which was used in this work (Figure 3 .1).

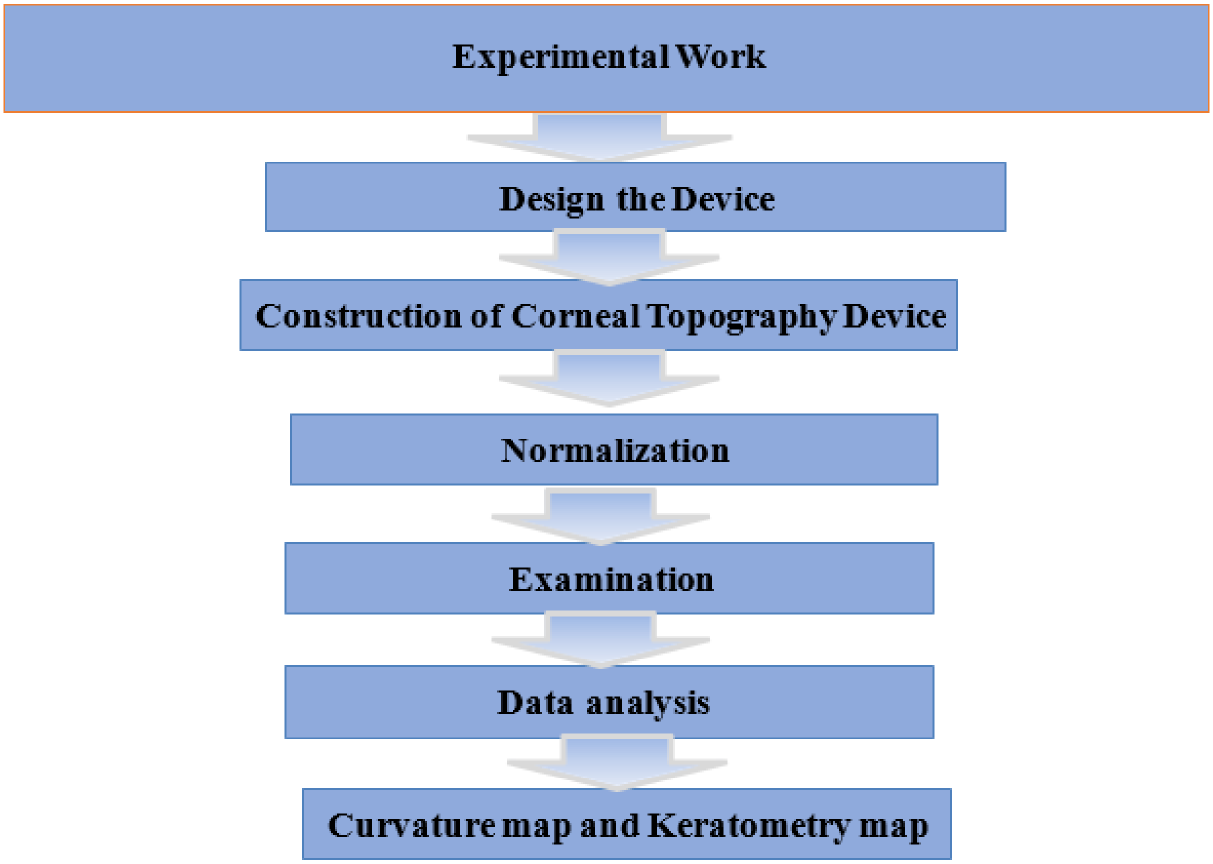


Figure 3.1: Schem of experimental steps

Design and Construction a proposed the corneal topography

The proposed design of the corneal topography device consists of a commercial USB camera connected to a personal computer with a holder to carry the camera as shown in Figure 3 .5. The camera contains white photodiodes to illuminate the area to be photographed

Figure 3 .2: The used camera in our proposal design

Figure 3 .3 shows a Placido disc designed with dimensions of 3 x 3 cm2. The design consists of 18 concentric white circles on a black background separated by a distance of 0.75 mm. The circular shape is divided into 9 equal sectors, and one of these sectors is cut off to form a conical shape.

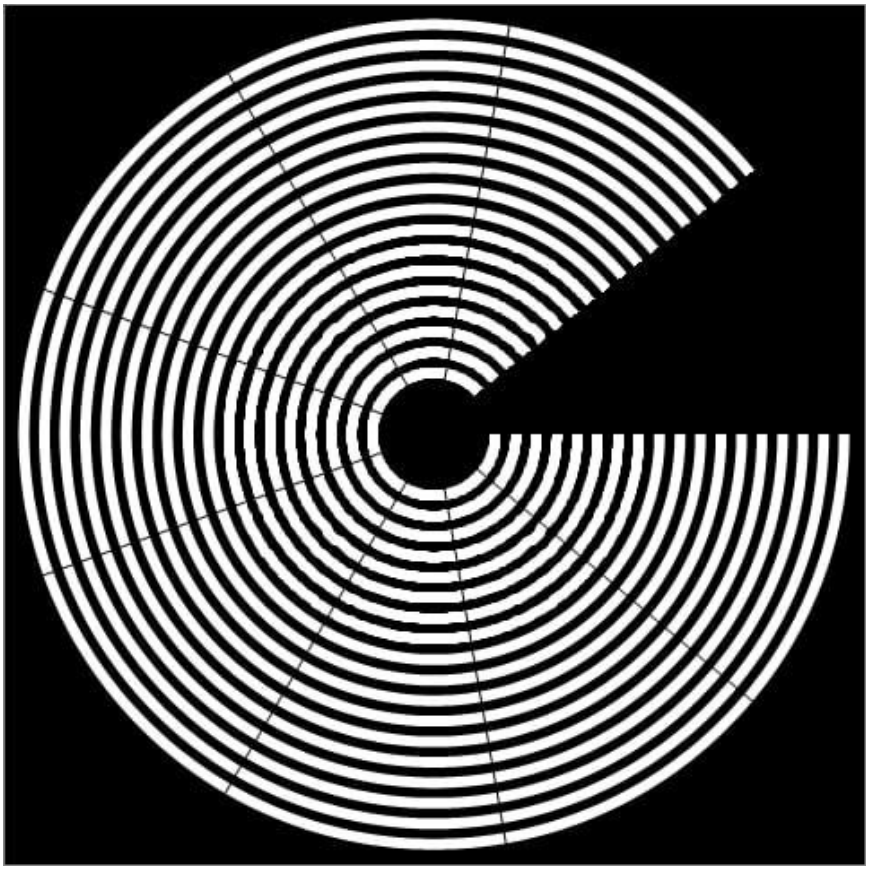


Figure 3 .3: The design and printed Placido disc

The printed shape on the paper was covered with transparent adhesive tape to keep it from damage. A hole was made in the center of the shape to allow the passage of light to the camera lens. The shape was wrapped and its two ends were glued to obtain a conical shape, with a circular base made in the back part, so that the height of the shape was fixed from the camera lens, as shown in Figure 3 .4. This figure is fixed inside the transparent frame at the front of the camera so that it is directed towards the patient's eye and the lighting is behind him to illuminate the white circles. A hole is made for the light to pass from the center of the conical shape to the camera lens after it is reflected from the tear film on the eye.

Figure 3 .4: Front and back view of the prepared cone

A brace was designed and manufactured to support the palate and another for the forehead to stabilize the patient's head while taking a corneal image. This stand is placed on a table with a height of 75 cm. A stand was used to hold the camera, locally available used for microphone setups. This holder can be adjusted in height and orientation to be located in the appropriate location in front of the cornea for image capture, as shown in Figure 3 .5.

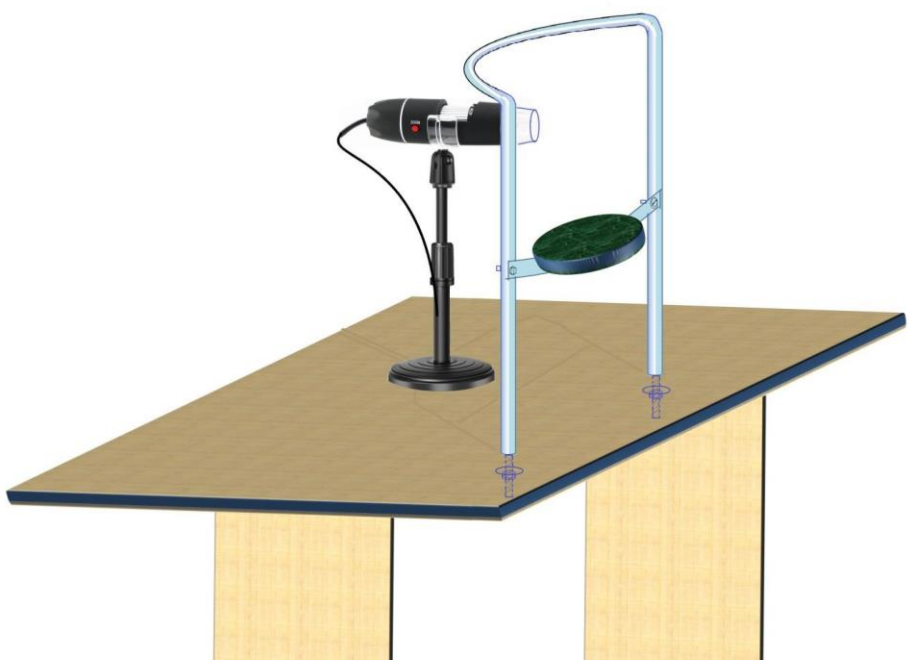


Figure 3 .5: The proposed corneal topography design

Three glass balls of different dimensions (D=12, 16, and 25 mm, i.e 6, 8, and 12.5 mm radius) were used in normalization process to find a relation between the line separation of reflected circles with the radius of the reflected surface. The diameter of the glass balls were determined using a micrometer.

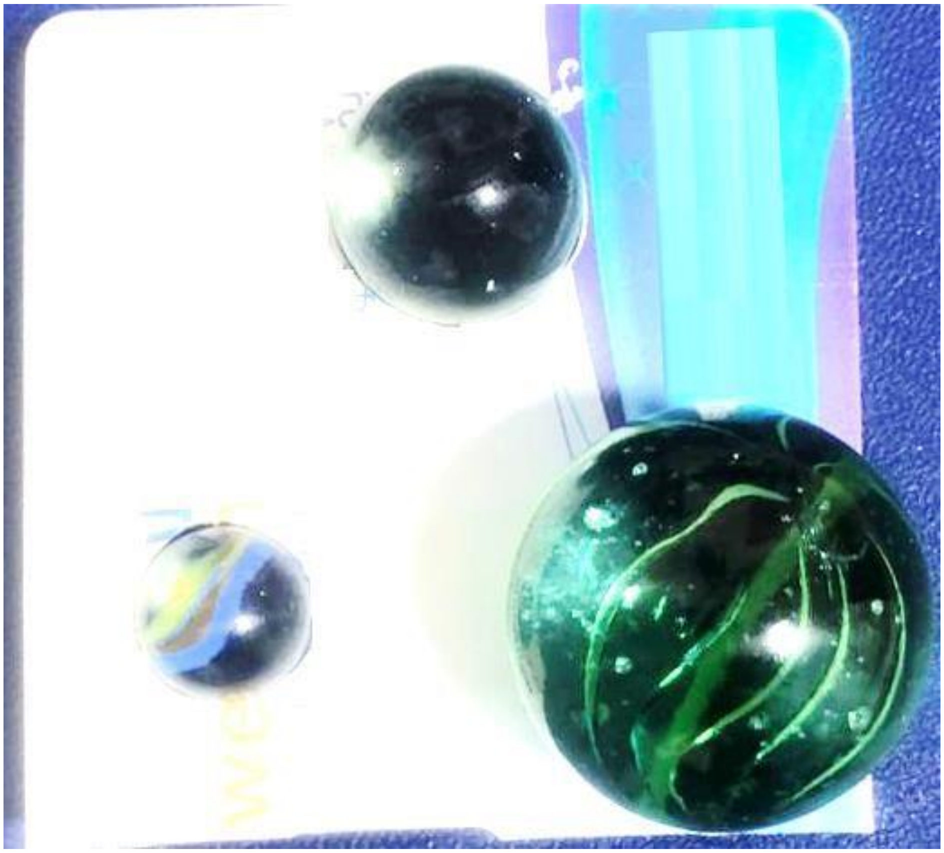


Figure 3 .6: The glass balls used for normalization process

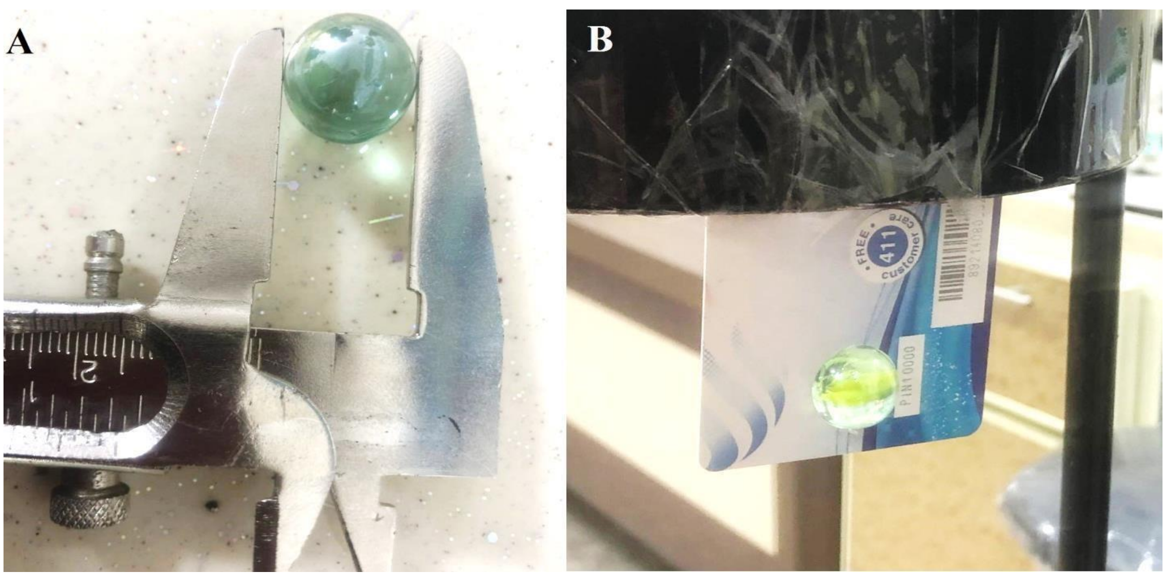


Figure 3 .7: Measurement of the glass balls diameter (A), and fixation the ball in the device (B).

The multiple coaxial rings cone was illuminated from its back by six white light LED. Figure 3 .8 shows the image captured from a glass ball of known radius for normalization process.

Figure 3 .8: Image taken from a glass ball of known radius for narmalization process

Figure 3 .8 shows the constructed of corneal topography device

Figure 3 .9: The constructed design

The patient is seated facing the device, which is raised to eye level. A bowl containing an illuminated pattern of a series of concentric rings. The light is focused on the anterior surface of the patient's cornea and reflected back throw a hall in the center of the pattern to a digital camera. The topology of the cornea is determined by the shape taken by the reflected pattern. The necessary analysis were done, typically determining the separation between the successive circles. The topographical map can be represented in a number of graphical formats, such as a sagittal map, which color-codes the steepness of curvature according to its dioptric value. Figure 3 .10 show an example of taken image of the reflected pattern from an eye of a patient.

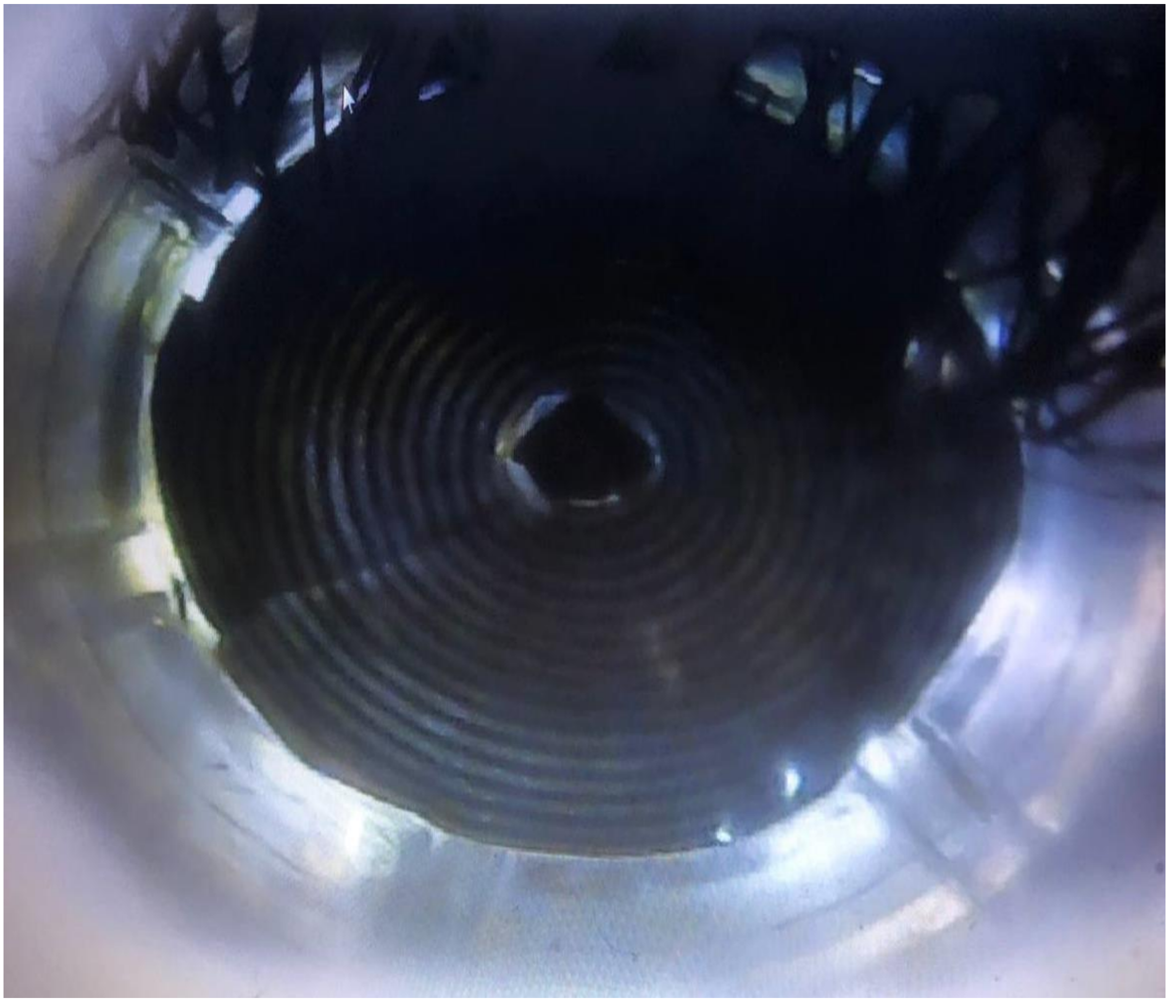


Figure 3 .10: An image of the reflected pattern from an eye of a patient.

Results and Discussions

Normalizing Process:

Figure 4 .1 shows the captured images of the reflected pattern of the concentric circles from the glass spheres of different radii of (6, 8, and 12.5) mm. Next to each image a gray level analysis of a randomly selected radial line is shown.

The selected line that starts from the center of the cornea to one of its edges and the gray level profile is drawn, where the white area is represented by a high value while the dark areas are low. The grayscale profile was analyzed using imageJ software, which used to find the locations of the white lines. The positions of the vertices are determined from this graph and used to find the locations of the circuits, and the separating distances between sequential circuits..

Figure 4 .2 shows the process of fitting the three images taken from the three spherical spheres with radii of (6, 8, and 12.5) mm. The blue line represents the experimental gray level, and the red line represents the curve fit and matched with least error using Excel. Each vertex is located. Then, these position values were used to determine the separation distances between the rings by subtracting every two consecutive peaks. This angle depends mainly on the radius of curvature, as it is close to the flatter surfaces and farther separations from the stepper surfaces.

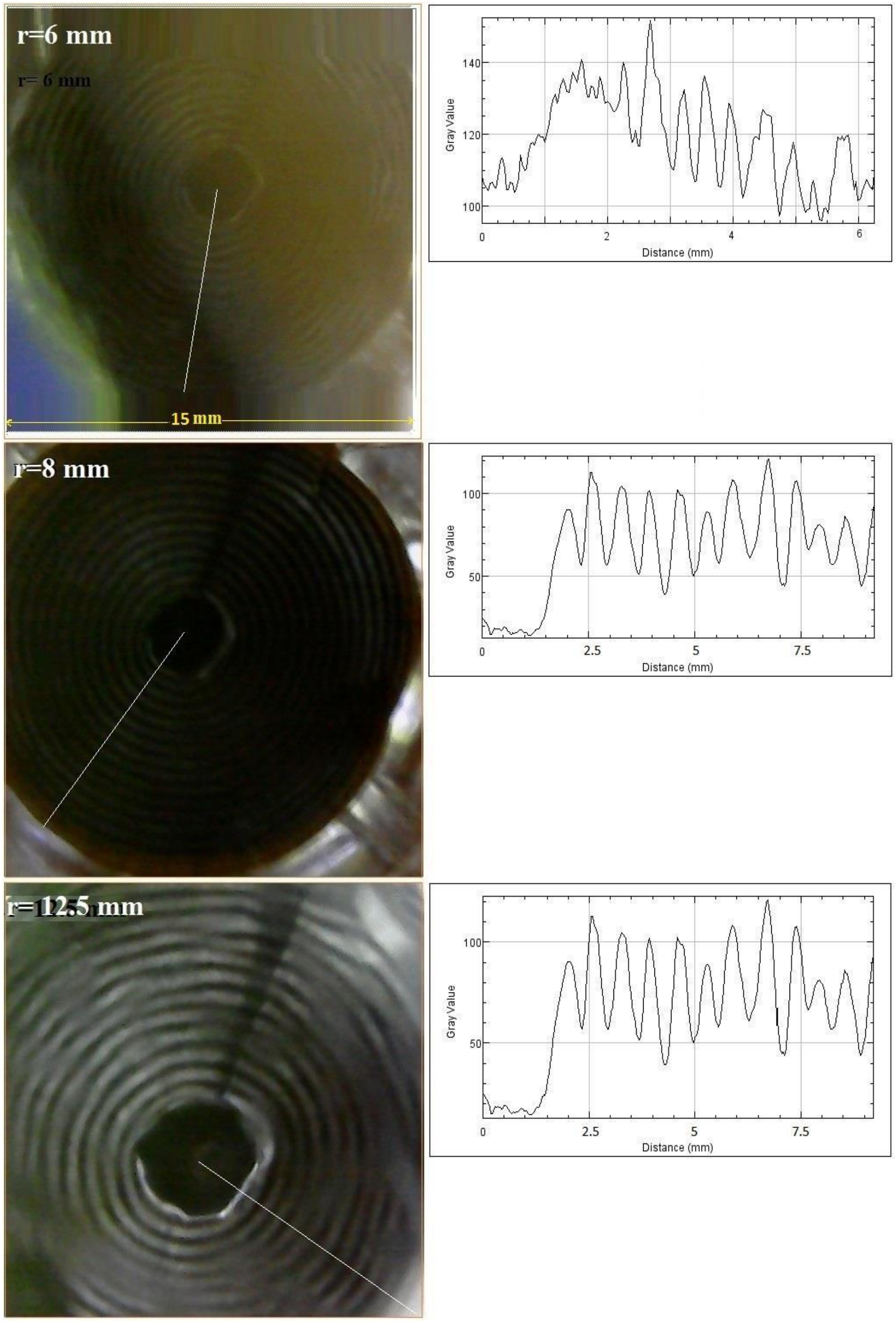
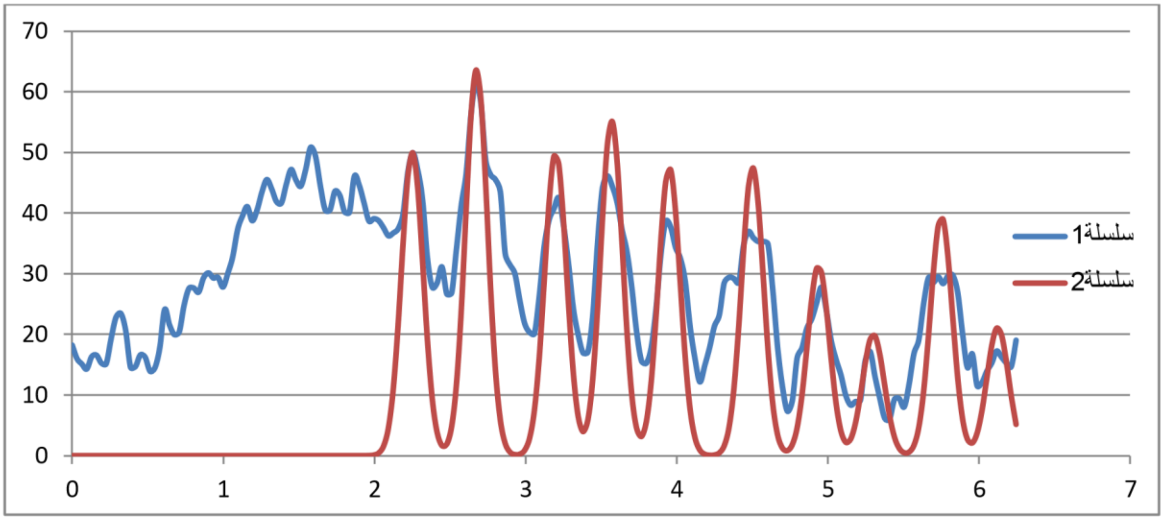


Figure 4 .1: reflected mire patterns from the three glass balls with different radius 6, 8, 12.5 mm and the gray level profile for the selected radial line.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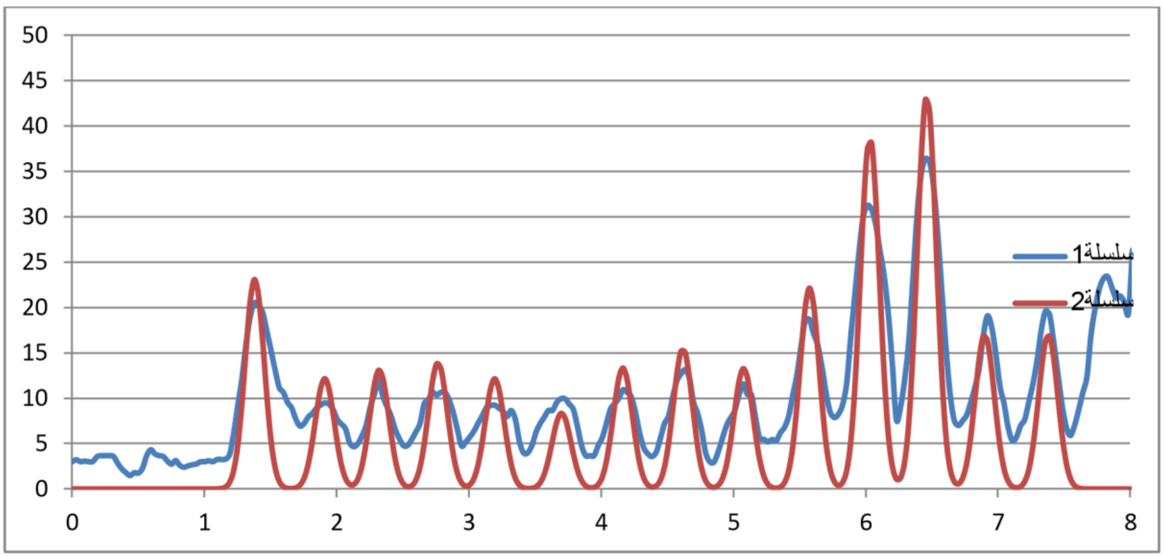
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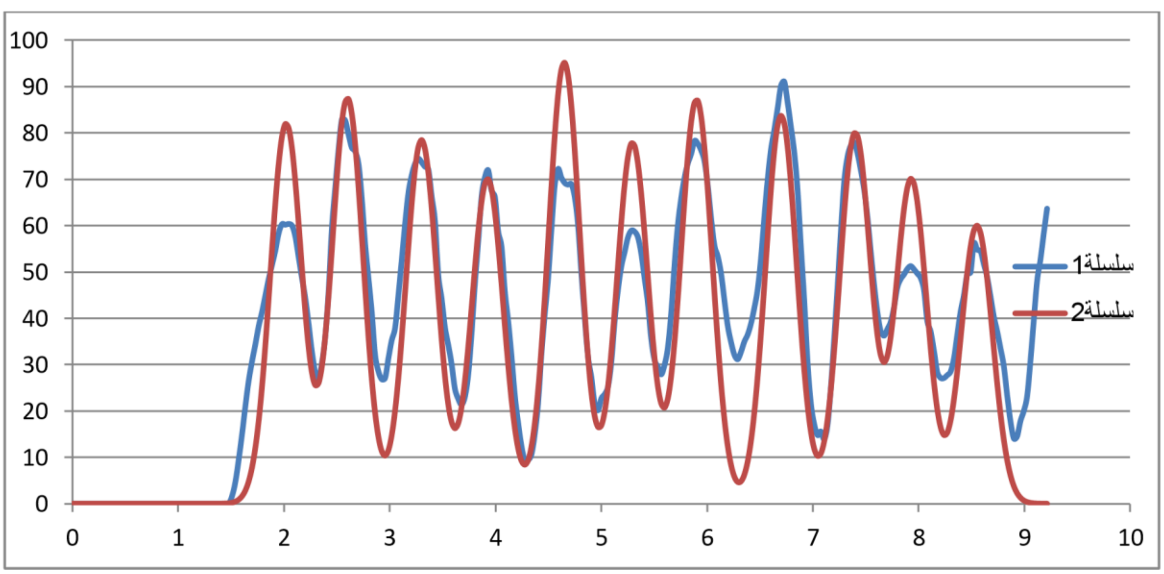

سلسلة1
سلسلة2

Figure 4 .2: The gray level profile at a selected radial path and their fitting for the three glass balls with different radius 6, 8, 12.5 mm.

By finding the average of the separation distances for the first case (radius 6 mm), the average of the second case (8 mm in diameter), and the average of the third case (radius 12.5), a calibration curve is found that gives the relation of the radius of curvature versus the separation distances, as shown in Figure 4 .3.

The fitting relation between radius of curvature versus average circles separation is:

y = 23.147x - 2.5319 ....4.1

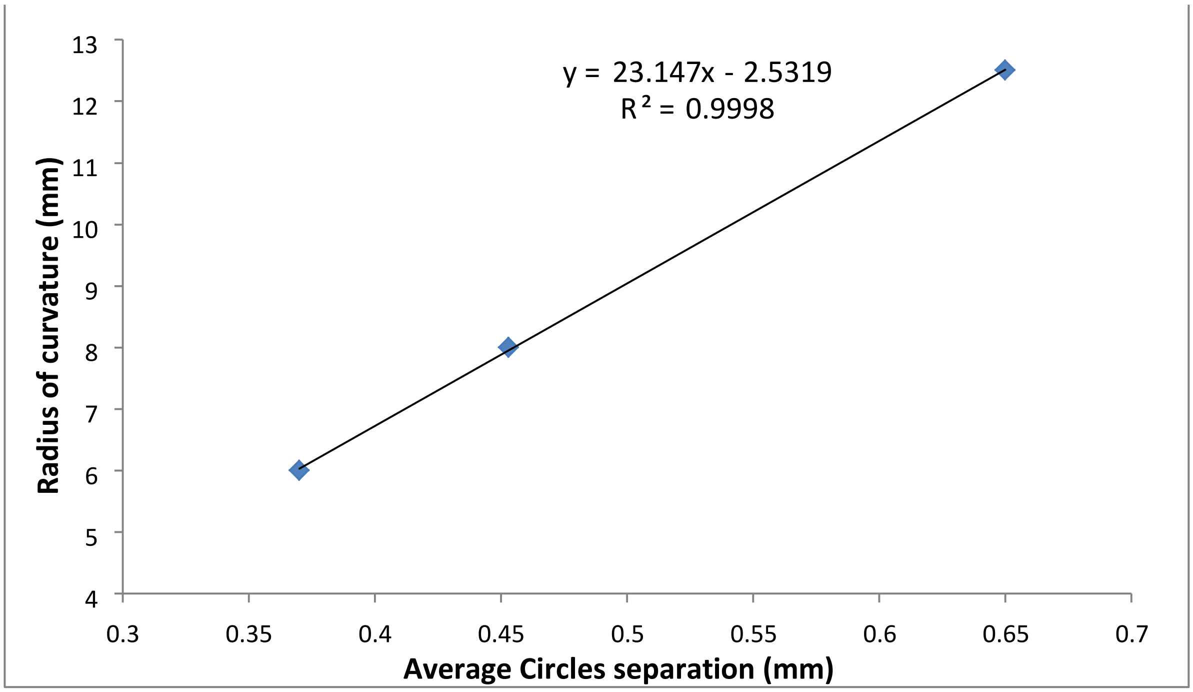
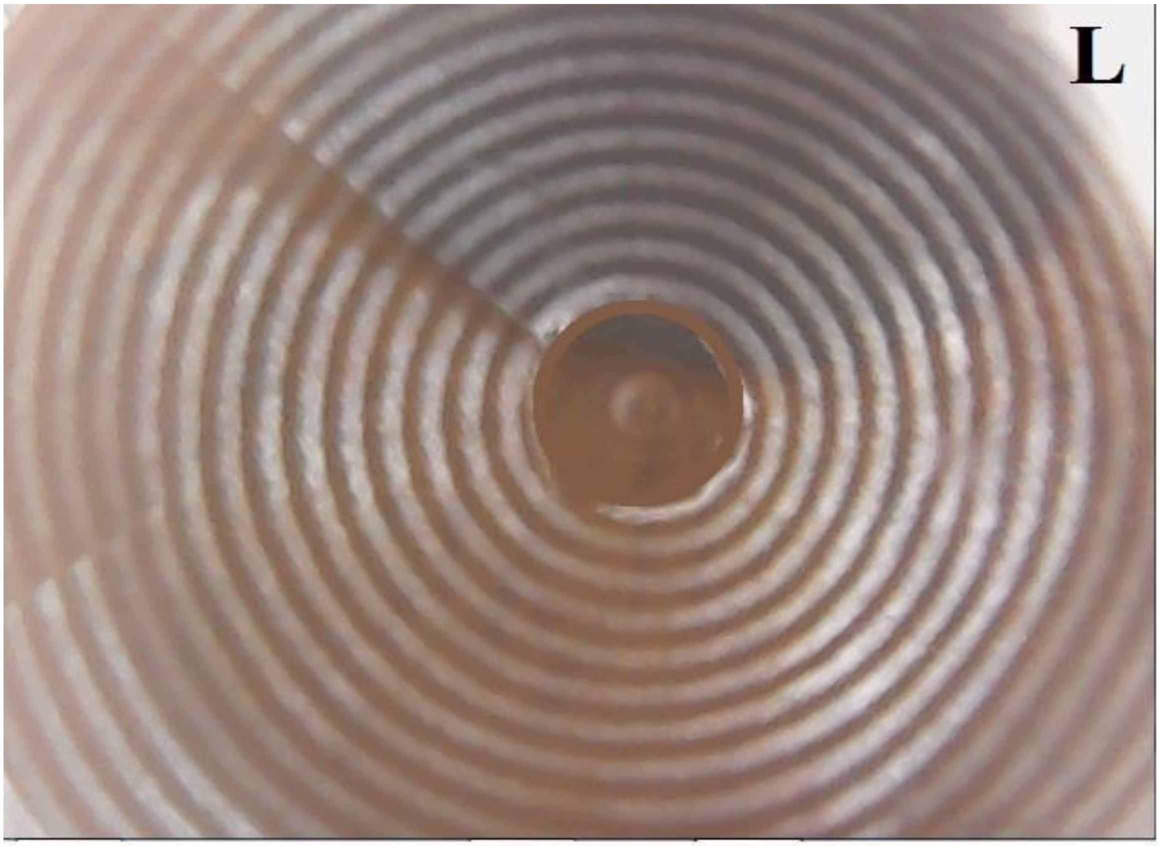


Figure 4 .3: The linear fit between radius of curvature versus the average circles separation of the reflected mire pattern

Figure 4 .4 shows the captured reflected from cornea of the patient's eye for the left eye and the right eye. The reflection of the circles reflected from the eye and centered in the pupil is clearly visible.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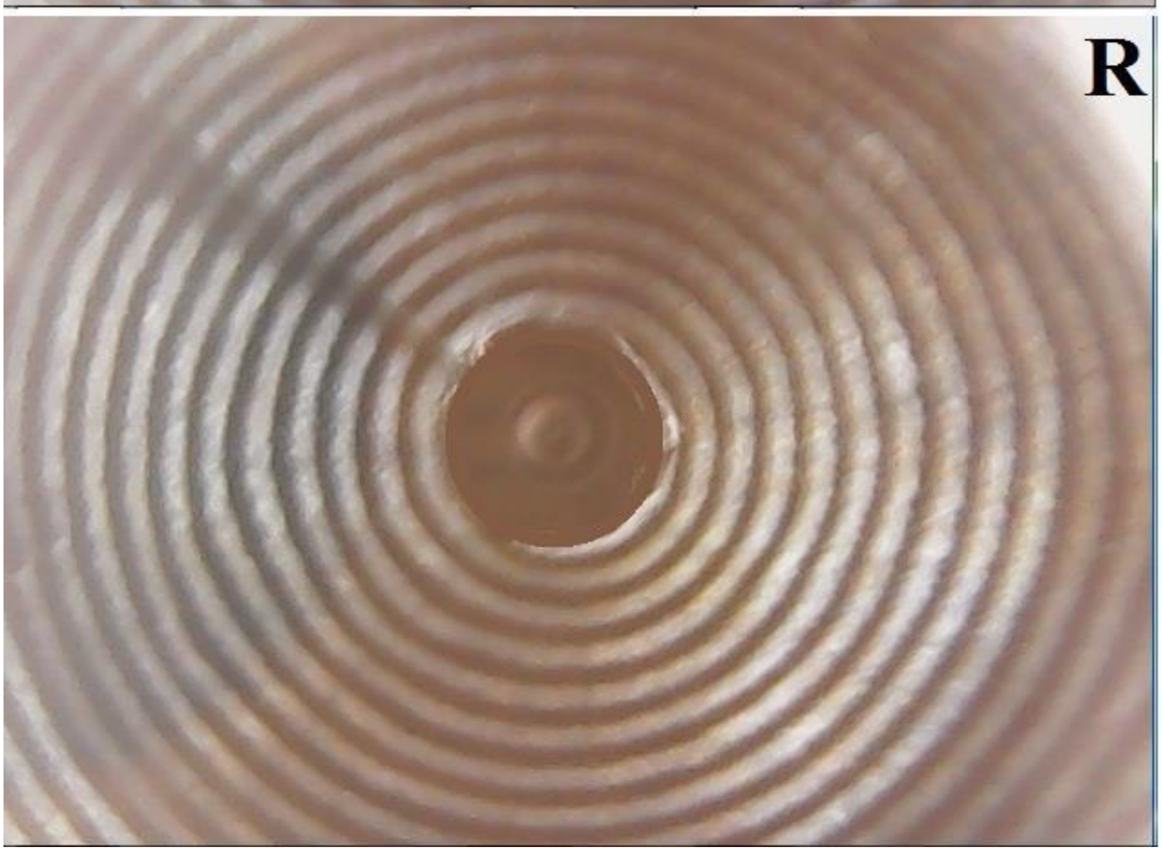
R

Figure 4 .4: Image for reflected from cornea of left and right eyes for a patient

The right eyes was selected to examine the possibility of determine its corneal topography. The image was filtered using MATLAB software with different filters include (the Contrast filter, Sharpening filter, and adjusting Thretiold) , respectively to clear the taken image as shown in Figure 4 .5.

Figure 4 .5: The reflected mire after image processing with different filters using Matlb software

The profile of gray level on the line from the circles center to radial direction for different angles (0, 45, 90, 135, 180, 225, 270, and 315°) were taken. As shown in Figure 4 .6.

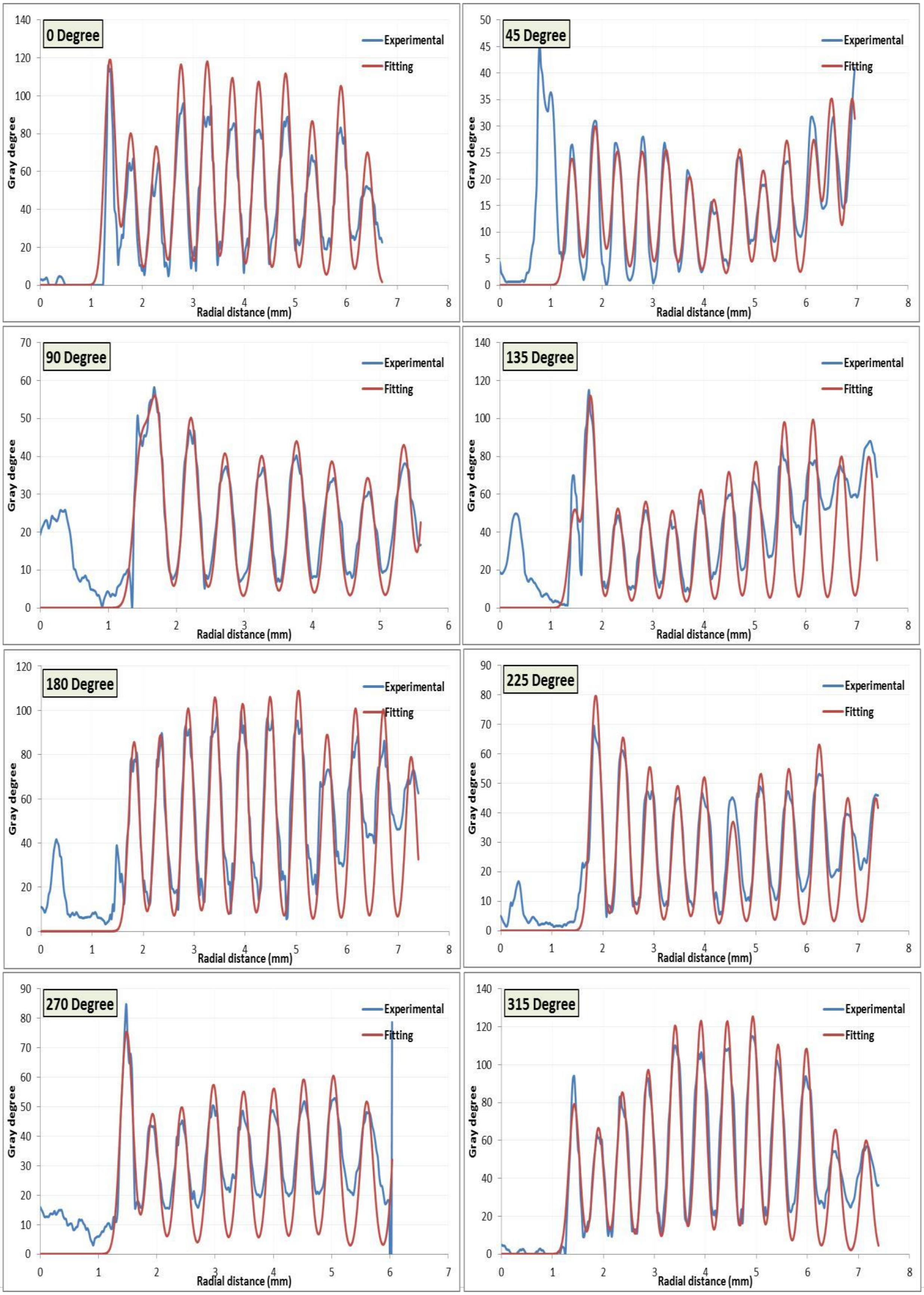
0 Degree
45 Degree
90 Degree
135 Degree
180 Degree
225 Degree
270 Degree
315 Degree
Experimental
Fitting
Gray degree
Radial distance (mm)

Figure 4 .6: The gray level profile at radial lines on different angles and their fitting to find.

The separation distances between any two successive rings of the reflected mire were used to calculate the radius of curvature according to the normalization relation (equation 4.1) for all the eight radial directions. These values were listed in Table 4 .1corresponding to each distance from the pupil center.

Table 4 .1: radius of curvature at different radial distance from the centre of pupil and different angles

Angle	0 45	90	135 180	225	270	315 r(mm)		
1.97	6.21	7.24	8.28	8.85	8.46	8.90	6.96	7.60
2.53	8.15	6.74	8.15	9.10	9.04	8.61	8.14	7.51
3.07	7.83	7.91	8.96	8.61	8.70	9.09	9.05	8.23
3.64	8.39	7.46	8.38	9.39	9.04	8.58	8.49	8.77
4.18	7.96	7.33	8.57	9.11	8.90	9.47	8.50	8.20
4.75	8.45	7.59	8.69	8.74	9.25	9.05	8.40	8.45
5.34	8.77	8.30	8.74	9.35	9.47	9.19	8.34	8.18
5.92	8.59	7.32	6.96	9.42	9.28	10.13	9.64	8.02
6.55	9.45	7.34	10.77	9.29	9.13	9.38	9.67	9.25
7.12	8.50	8.68	8.10	8.89	9.03	9.18	8.19	9.57

The average values for radius of curvature (r) for the three zones (0-3, 3-5, and 5-7 mm) were determined as listed in Table 4 .2

Table 4 .2: the averag of radius curvature at three zones of 3, 5, 7 mm at different angles

Angle / Zone(mm)	0	45	90	135	180	225	270	315
0-3 mm	7.4	7.3	8.5	8.9	8.7	8.9	8.0	7.8
3-5 mm	8.3	7.5	8.5	9.1	9.1	9.0	8.5	8.5
5-7 mm	8.8	7.9	8.6	9.2	9.2	9.5	9.0	8.8

The keratometry values were determined from the r values according to the relation:

$$k = \frac{337.5}{r\ (mm)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.2$$

Table 4 .3: the average of keratometry values at three zones of 3, 5, 7 mm at different angles

Angle / Zone(mm)	0	45	90	135	180	225	270	315
0-3 mm	45.6	46.3	39.9	38.1	38.6	38.1	41.9	43.4
3-5 mm	40.8	45.3	39.5	37.2	37.2	37.4	39.9	39.8
5-7 mm	38.2	42.7	39.1	36.5	36.6	35.6	37.7	38.5

Figure 4 .7 shows the radius of curvature values located on their zones of 3, 5, and 7 mm diameters.

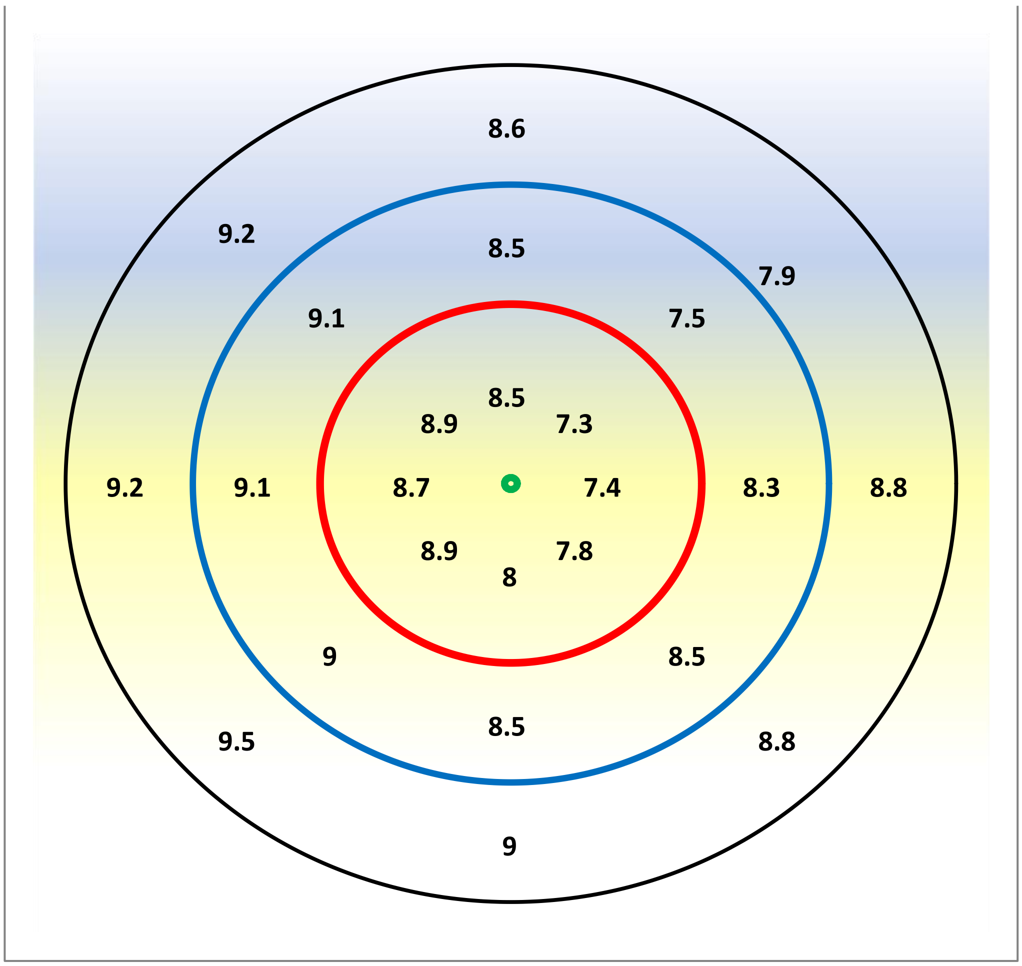

Figure 4 .7: The determined radius of curvature values for 24 points in the three zones (3, 5, and 7 mm) for the right eye of the patient

Figure 4 .8 shows the keratometry values located on their zones of 3, 5, and 7 mm diameters.

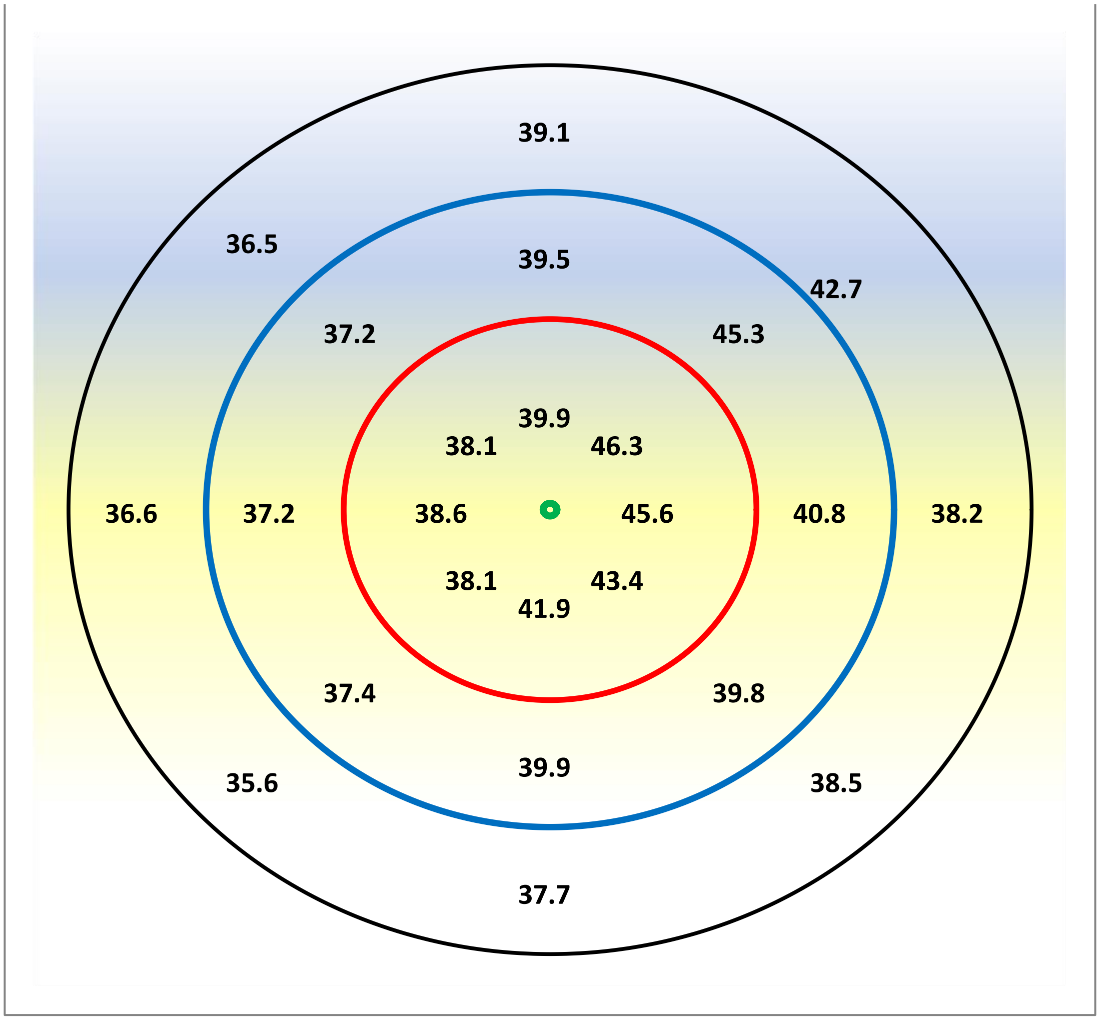

Figure 4 .8: The determined Keratometry values for 24 points in the three zones (3, 5, and 7 mm) for the right eye of the patient

Figure 4 .9 shows the generated keratometry map and radius of curvature map using Origin software by drawing a colored contour for keratometry (k) and radius of curvature (r) values. The corneal topography appears after a program has been applied. Through these pictures that the (k) values range from 35.6 with blue color to 46.3 with red color. While, the r values range from 7.3 to 9.5 mm with gradient colored from blue to red. The patient seems has irregular astigmatism.

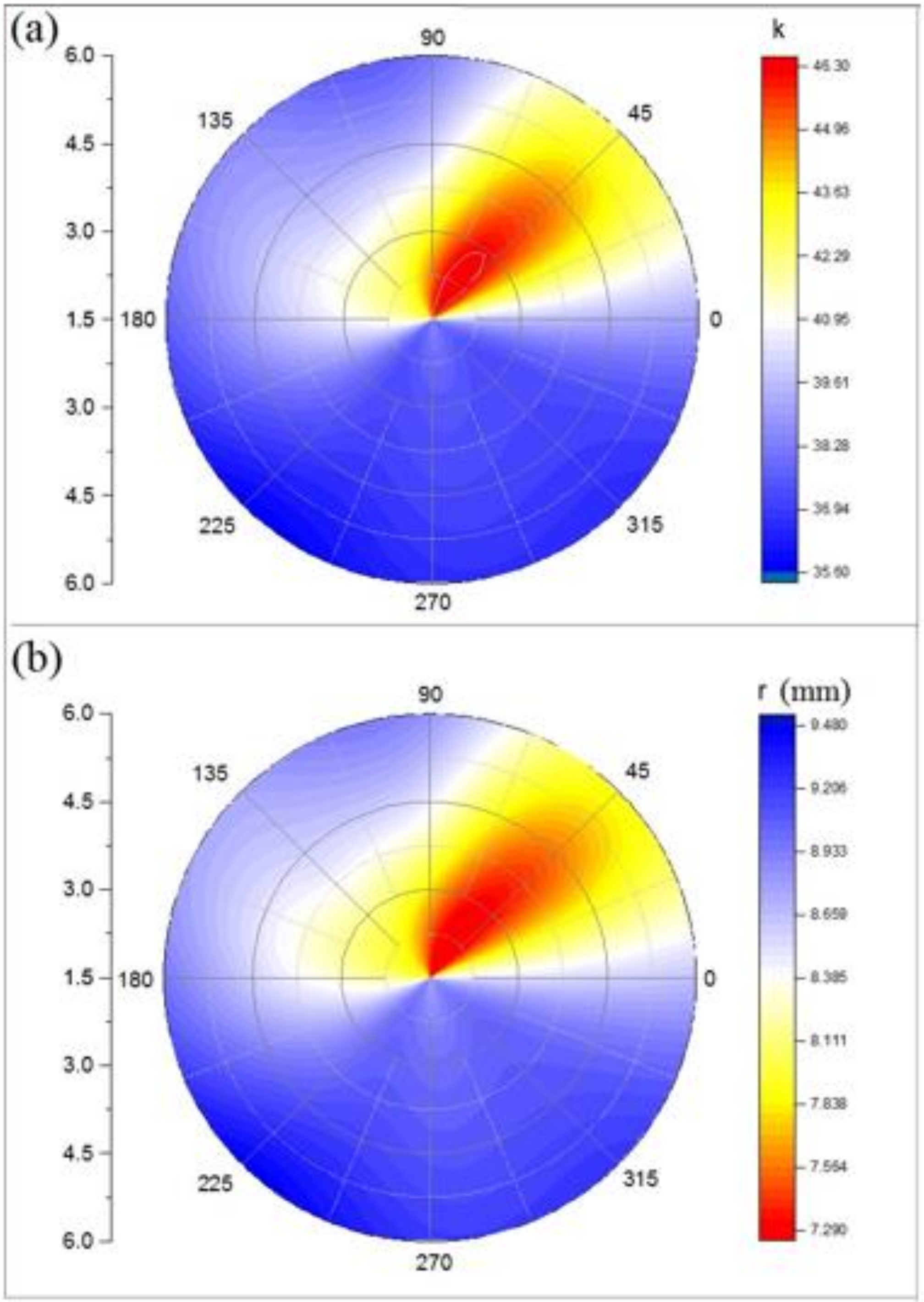

Figure 4 .9: The determined Keratometry map (a) and radius of curvature map

Conclusions

A new and straightforward device for examining a corneal topography based on Placido disk, which depends on capturing the reflection image of a shined concentric rings pattern separated by fixed distances from the surface of the cornea.

The built device was calibrated using three glass balls of different radii by calculating the average distances between the reflected rings corresponding to the radius of curvature.

Photographs of the reflection of the illuminated pattern were taken from the eyes of a patients is successfully analyzed.

The device showed the possibility of analyzing the curvature and keratometry maps. The consulting of a specialist doctor determined the type of refractive error that the patient suffers from, which was determined as asymmetrical astigmatism due to a slight deformity in the cornea.

Recommendations

1. Topographical study of the eye with different corneal curvature problems.
2. Compare the results with certified devices to measure corneal topography
3. Drawing topographical maps of the eye, which includes elevation map.

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