CHAPTER 3

EXAMINING THE CONTACT LENS PATIENT [86–89]

All contact lens patients should receive regular comprehensive ophthalmic examinations. These examinations should include tonometry, fundus examination (dilated if necessary), anterior segment examination, evaluation of binocular status and basic neurological functions, as well as refraction. It is also recommended that tonometry and fundus examinations are performed at each-and-every follow up examination to ensure the continued visual health of these patients.

THE SLIT LAMP BIO-MICROSCOPE

Since the 3rd August 1911 when Allvar Gullstrand demonstrated his new invention, the slit lamp, for the first time, this instrument has gone through many improvements resulting in the binocular high magnification and high illumination instruments we use on a daily basis in ophthalmic practice. Gullstrand's invention has been described as "an occasion of tremendous significance to ophthalmology". Not only was Gullstrand responsible for the invention of the slit lamp but for the retinal camera as well. As students of the ophthalmic sciences you will have studied the different illumination and examination techniques including diffuse illumination, optic section, tangential illumination, sclerotic scatter, retro-illumination and their uses extensively and you should therefore be familiar with the use of the instrument. An ophthalmic examination is not complete without a slit lamp examination and this instrument will become as familiar as your right hand after frequent use. The examination is seamless, and all illumination techniques are typically employed when examining the patient. Many ophthalmic textbooks will have excellent overviews of the different illumination and examination techniques. These techniques should be reviewed as they will not be covered in this text.

CONJUNCTIVA, CORNEA, SCLERA AND LIDS

After observing the patient in general room illumination and noting any abnormalities of the eye and adnexa, the slit lamp can be employed to examine these structures under high magnification and different illumination techniques to reveal abnormalities not readily seen with the naked eye. The conjunctiva should be examined under diffuse illumination looking for signs of injection, desiccation, prominent surface vessels, pterygiums, pingueculas and other irregularities such as follicles and papillae. The examination should include the bulbar as well as tarsal conjunctiva and the use vital dyes are recommended.

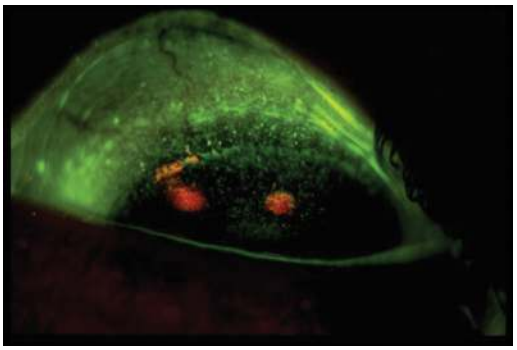

Figure 15: Superior limbic keratoconjunctivitis (SLK)

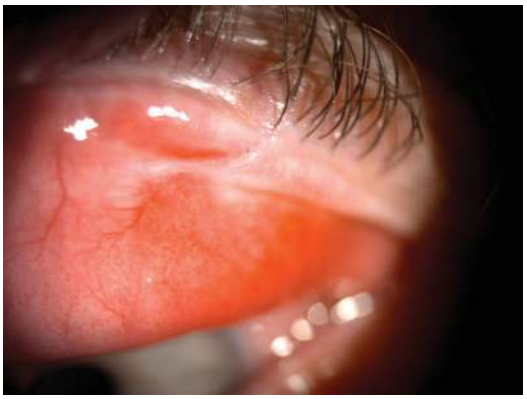

Figure 16: Scar from previous lid surgery

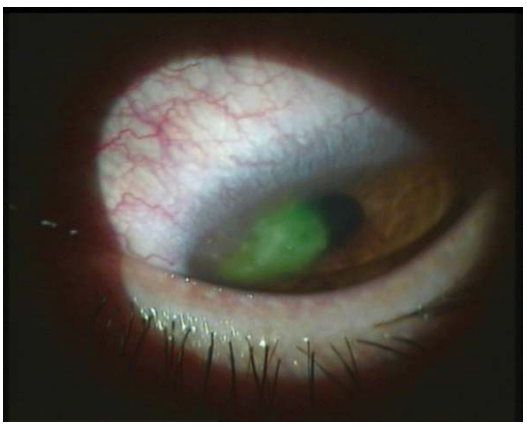

Figure 17: Corneal staining and scarring, resolving corneal ulceration

The cornea should be carefully examined using all the illumination techniques as well as different levels of magnification. Any abnormalities should be carefully noted on the record card for future reference. Look for signs of vascularisation, corneal scars, corneal infiltrates, prominent nerves, thinning or thickening, desiccation, clarity, pannus and integrity of the endothelium. Vital dyes are highly recommended and will be discussed at length later in this chapter.

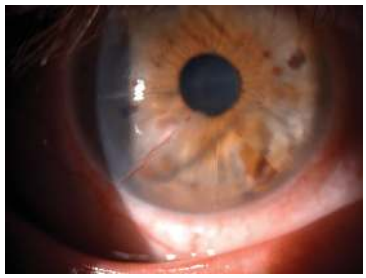

Figure 18: Corneal neovascularisation in a patient with previous radial keratotomy surgery

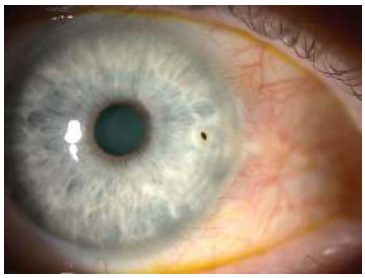

Figure 19: Ferrous metal corneal foreign body

Figure 20: Corneal hydrops in patient with keratoconus

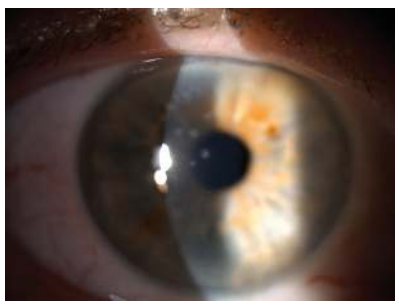

Figure 21: Sub-epithelial infiltrates (SEIs) in a patient with epidemic keratoconjunctivits

The lids should be examined under diffuse illumination and then the other techniques should be employed to specifically look at the position and size of palpebral aperture, lid tension, regularity of the lid margin, signs of blepharitis, Meibomian gland disease, styes and cysts, completeness and frequency of the blink, lid wiper epitheliopathy, tarsus and general condition of the skin should be looked at. Blepharitis should be classified, and the cause established. Specifically examine the roots of the cilia for evidence of *Demodex folliculorum* and if suspected remove a cilium for inspection under a light microscope.

Figure 22: Chronic anterior blepharitis

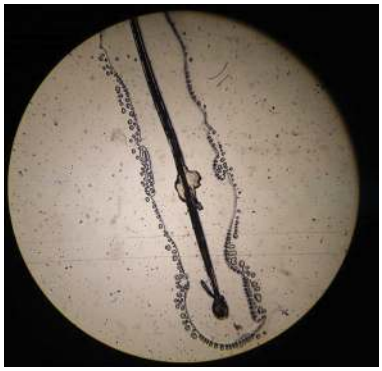

Figure 23: Eyelash with Demodex mite attached

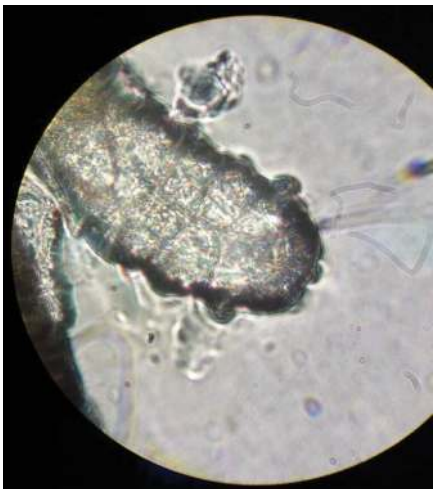

Figure 24: Enlarged view of Demodex mite's head

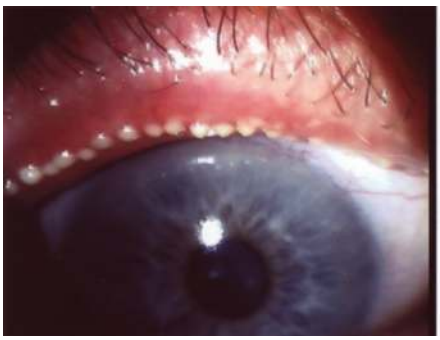

Figure 25: Meibomian gland disfunction (MGD)

MEASURING THE CORNEA AND SCLERA [86–89]

The normal cornea has an elliptical prolate shape which is steeper at its apex and flattens toward the periphery. Corneas that have undergone refractive or other surgery have an oblate shape which is flattest at its apex and steepens toward the periphery. Corneal Eccentricity (*e* value) refers to the rate at which the cornea flattens from the central area to the peripheral area. Average corneal *e* values are 0.45–0.50 and $e > 1$ indicates pathology such as keratoconus. While, $e < 0$ typically indicate corneas that have had corneal surgery/refractive procedures. Shape factor (*p* value) and eccentricity are related, and the following formula can be used to convert one to the other: $p = 1- e^2$. Shape factor is used to describe aspheric surfaces. A shape factor $p = 1$ indicates a spherical surface, $p > 1$ a radius that steepens toward the periphery and $p < 1$ a surface that flattens toward the periphery.

Keratometry

In the past the corneal curvature was measured using a keratometer or ophthalmometer. It was invented by the German physiologist Hermann von Helmholtz in 1851. The instrument records the image size reflected off a known-sized object. The object has two separate mires at distinct distances reflects off the central 3.2 mm the cornea. The device assumes that the cornea is spherical and has a refractive index of n = 1.3375 compared to the actual corneal refractive index of n = 1.376. This is a fictional value, which includes an allowance for the small yet significant negative power of the posterior corneal surface. Although different instruments are available most clinicians prefer either the Bausch & Lomb or Javal-Schiotz keratometer. The difference between the two instruments is the appearance of the mires and the fact that with the Bausch & Lomb instrument the object size is fixed, and image size has the manipulable variable which is not the case with the Javal-Schiotz instrument (Figures 25 and 26).

Keratometry provides information regarding the radii of curvature of the cornea, the directions of the principal meridians of the eye indicating whether the astigmatism is with or against-the-rule, the degree of astigmatism and if any corneal distortion is present. The major disadvantage is that it only measures the central 3.2 mm of the cornea.

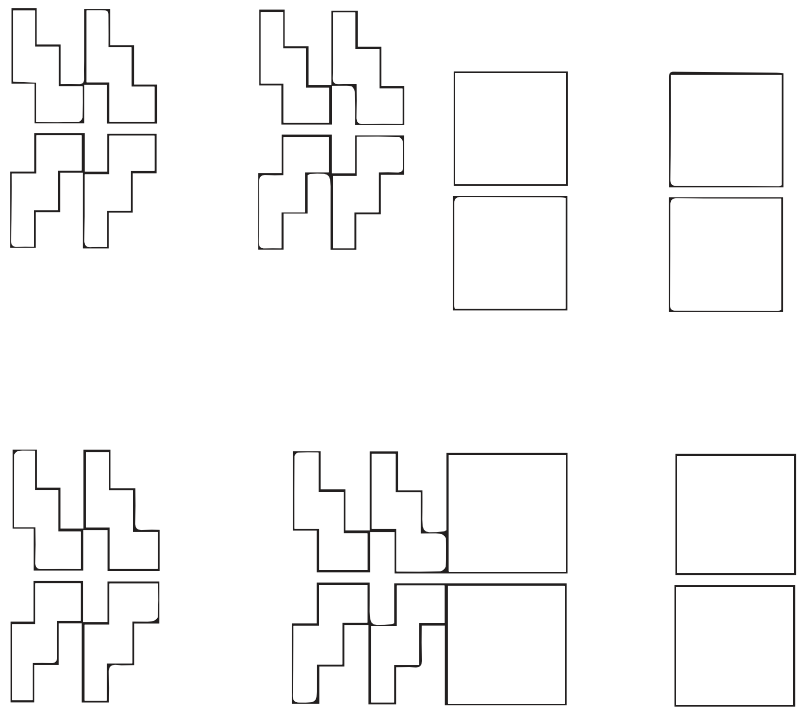

Figure 26: Javal-Schiotz keratometer mires

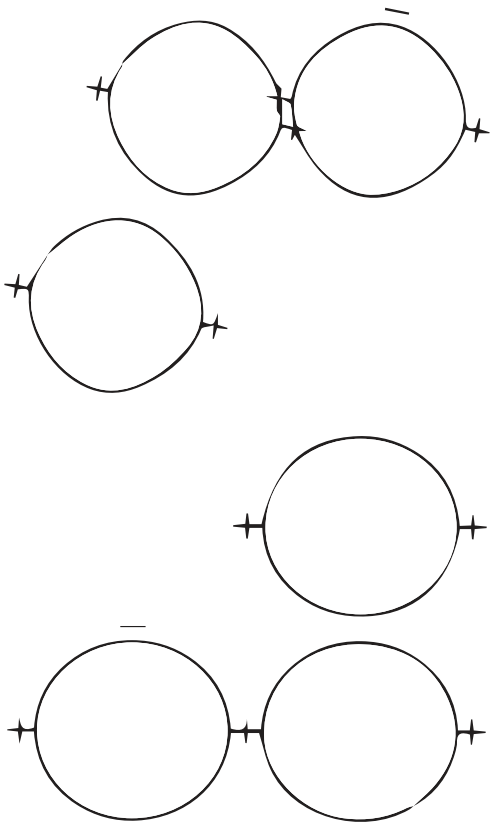

Figure 27: Bausch and Lomb keratometer mires

The Placido Disc, Photokeratoscope and Corneal Topographer [90–92]

The first known keratoscope target was the image of a window as reported by Scheiner in 1619 using natural light. He estimated the corneal curvature by comparing the window pane corneal reflection to those of a series of marbles until he found one that gave an image the same size as that of the cornea. In 1820 Cuignet developed a keratoscope through which he observed the reflected image of an illuminated target held in front of a patient's cornea. His major problem was in the alignment of the light, target and observer with the patient's visual axis. This was overcome in 1882 by Placido, who placed an observation hole in the centre of the target. Placido's target of alternating black and white rings (the Placido disk) has been embodied in many devices that are currently used to measure corneal topography. Hence, the term Placido disk keratoscopy. Simultaneously, information regarding the radius of curvature of a localised area of the cornea can be obtained by observing the separation between the mires reflected from that area of the cornea. In areas of steep cornea, the images of the mires are smaller, so the rings appear narrower and closer together. In the presence of regular astigmatism, the mires appear elliptic. The short axis of the ellipse corresponding to the meridian of corneal steepening and highest power. Irregular astigmatism produces non-elliptic distortion of the mires. For the most part, photokeratoscopes yield qualitative information that is clinically useful as a means of evaluating changes in the peripheral cornea, such as in the detection of the corneal ectasia associated with keratoconus, or as a guide to selective suture removal after penetrating keratoplasty. Its limitations are that it provides no information about the central 3 mm of the cornea and that up to 3 dioptres of cylinder may go undetected by visual inspection of photokeratographs.

Quantitative analysis of photokeratograms became practical when Gullstrand in 1896 applied photography to keratoscopy (photokeratoscopy). This allowed the clinician to fix the image and measure the size of the rings.

However, this analysis is slow and subject to major errors. In the 1980s, computer power was adapted to the task of automated high-resolution corneal topography analysis, which is most popularly implemented in commercially available computer-assisted videokeratoscopes such as the Topographic Modelling System (TMS-1, Computed Anatomy, New York, NY) and the Corneal Analysis System (Eyesys Laboratories, Houston, TX). These devices were devised to overcome the deficiencies of photokeratoscopes, both in speed, and in gathering quantitative information about the anterior corneal surface. Most systems use illuminated Placido-type mires with nose-cones that provide a broad area of corneal coverage from the apex to the limbus of the cornea covering approximately 11 mm of cornea. These novel conical mire targets provide very high radial resolution being approximately 0.17 mm apart reflected on the normal corneal surface. Additionally, the central fixation light and the first mire of the standard cone provide excellent central corneal coverage ensuring that corneal topographic details important to visual function are not obscured as they are with keratometers and traditional keratoscopic targets. Because direct measurements are made from the centrally visually important area as well as from the periphery, a clinically complete data set derived from between 6000 and 22000 data points on the cornea is available for clinical interpretation. Other advantages of videokeratoscopy over photokeratoscopy are its speed in gathering quantitative information and its ability to display data in a clinically useful format with reasonable accuracy. Although the raw Placido image provides data of corneal pathology, tear break-up time as well as quality, the most useful form of data presentation is a color-coded corneal contour map. Steep areas are depicted as “hot colours” such as reds and browns and hallow areas as “cool colours” such as blues and greens. Two scales are commonly used; absolute and normalised or relative scale. These colour scales appear on the left margin of the map with the flattest curvature at the bottom and the steepest curvature at the top. The absolute or standard scale displays a fixed range of curvatures selected in the settings of the topographer regardless of the map selected. The normalised/relative scale displays the range of curvature or power calculated from the specific map(s) you select. This provides an excellent general view of the entire cornea as the scale shows the flattest to steepest readings. In the normalised scale, more minute topographic details within an individual cornea are appreciated.

The axial map is used most often since axial curvature is directly related to corneal power. This allows you to correlate the axial map display of steep areas in hot colours (red) and flat areas in cool colours (blue). These colours directly correspond with the curvature data on the scale displayed at the left when viewing the image. The tangential map clearly defines changes. It calculates each measured point of data at a 90° angle to its surface. Tangential maps provide a more detailed description of the corneal shape and provide a clearer view of the size and shape of the cone in a keratoconus patient. The ability to measure the size of the cone is very helpful in determining the ideal lens design and optic zone size. Additionally, tangential maps define the position of the treatment or effect of corneal reshaping and refractive surgery.

The refractive power map provides an interpretation of the quality of vision a patient may achieve from the corneal surface throughout the pupillary zone. The more consistent or uniform the refractive power within the margins of the pupil, the better the anterior surface of the cornea will refract light. Practitioners do not commonly employ the refractive map as it does not provide information on curvature or size and shape of the corneal surface (for which the axial and tangential maps are more effective). However, this map can be very effective when used to interpret the quality of vision achievable from a patient’s corneal surface. For instance, when comparing pre-corneal vs. post-corneal reshaping results, the refractive map illustrates the extent to which the corneal surface changes contribute to the patient’s quality of vision and the position of the effect of treatment in relation to the pupil. Thus, the refractive power map can aid you in determining how well the patient sees, specifically highlighting the contribution of the corneal surface to visual acuity. Additionally, following corneal reshaping or refractive surgery, it can show you how well or how poorly the effect is positioned. The elevation map defines the height of the cornea

referenced to “best fit sphere”, or the radius of curvature that best matches the average curvature of the map. Placido disc topography systems do not actually measure elevation, they rather gather elevation data by reconstructing actual curvature measurements via sophisticated algorithms. Elevation maps measure corneal height in microns and have a somewhat counterintuitive interpretation. Elevation is defined as the difference between the actual corneal surface and the best-fit reference sphere as measured in microns.

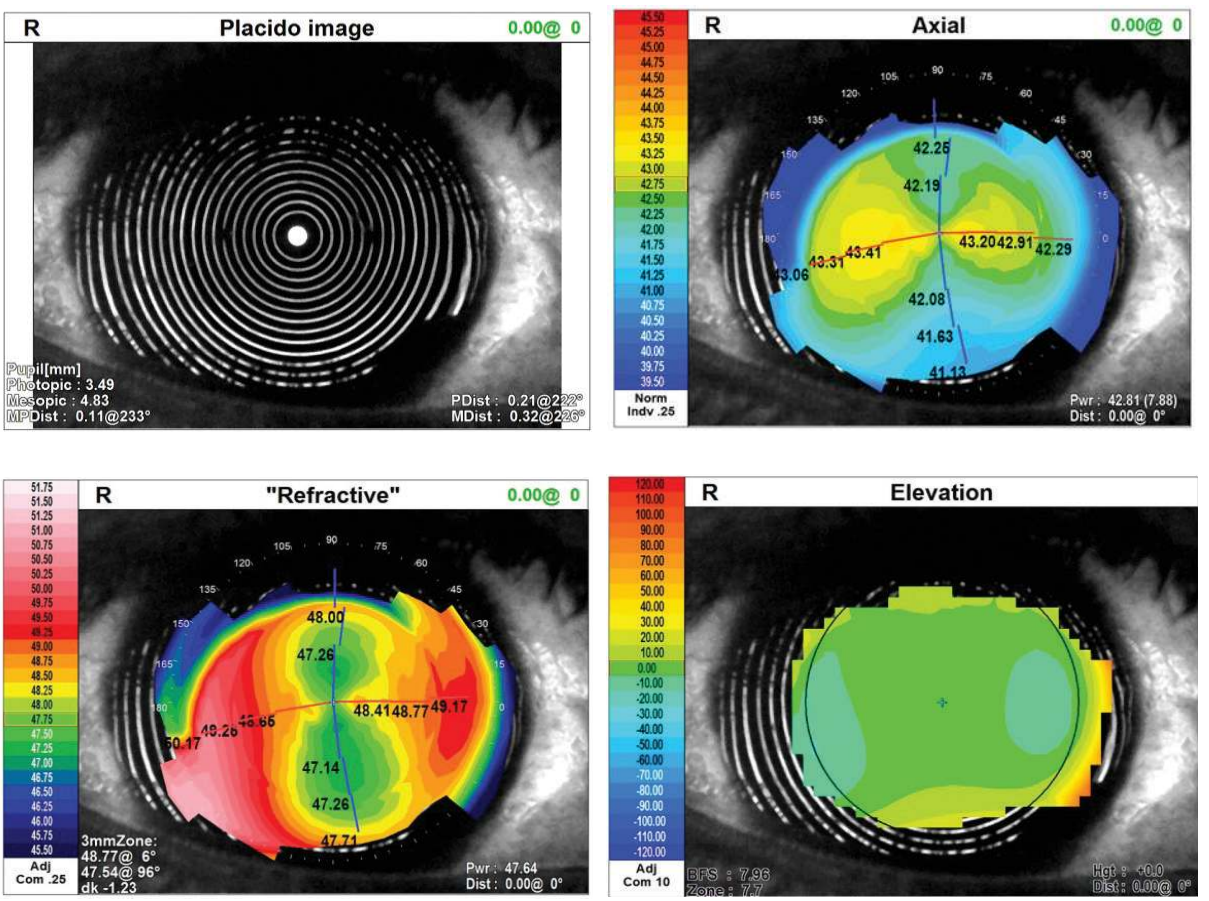

Figure 28: Typical maps from a corneal topography system

Corneal topography systems also generate quantitative indices, including the following; predicted visual acuity based on corneal shape, simulated keratometry readings, minimum keratometry readings, corneal shape factor, corneal eccentricity, surface regularity index and surface asymmetry index. The indices vary depending on which system is used and I will only list those produced by the Oculus Keratograph (Oculus, Wetzlar, Germany) (Table 13).

In addition to measuring the anterior curvature and shape of the cornea, some of the newer systems also provide software to analyse the non-invasive tear break-up time, contact lens fitting simulations, higher order aberrations as well as Zernicke Polynomials. Corneal topography systems are more accurate and provide much more information than traditional keratometers. However, the measurement is of the front corneal surface only and the central 2 mm of the cornea is not measured due to the position of the camera.

Table 13: Diagnostic indexes used by the Oculus corneal topography system [93]

ISV - Index of surface variance	Deviation of individual corneal radii from the mean value Elevated in all types of irregularity of the corneal surface
IVA- Index of vertical asymmetry	Degree of symmetry of the corneal radii with respect to the horizontal meridian Elevated in cases of oblique astigmatism, keratoconus and limbal ectasias

KI – Keratoconus index	Elevated especially in Keratoconus
CKI – Centre Keratoconus index	Elevated especially in central Keratoconus
RMin	Smallest radius of curvature in the entire field of measurement Elevated in Keratoconus
IHA–Index of height asymmetry	Degree of symmetry of height data with respect to horizontal meridian Analogous to IVA, sometimes more sensitive
IHD– Index of height decentration	Calculated from a Fourier analysis of height values Index gives the degree of decentration in vertical direction Elevated in Keratoconus
ABR– Aberration coefficient	Calculated from a Zernike analysis 0 = no abnormal corneal aberrations As value increases past 1, the abnormal corneal aberrations increase
KKS– Keratoconus stage	Classifies Keratoconus according to Amsler's classical staging schema*
AA– Analysed area	Area of corneal surface measured as a percentage

Scheimpflug or Pentacam Corneal Tomography [91]

Corneal topography using a computer-aided system was developed in the 1980s and can be used to display an undistorted image of the curved corneal surface. However, as mentioned previously, the camera is placed at the centre of the imaging instrument (placido disc) resulting in a central 1 to 2 mm area of the cornea not being measured. Individual tear film characteristics can also influence the accuracy of the images. The rotating Scheimpflug camera overcomes these inadequacies by scanning the entire cornea with the same precision, independent of the individual tear film [94]. The Pentacam (Oculus, Wetzlar, Germany) generates real-time images of the actual eye segments, creating a precise three-dimensional view of the anterior segment including the central cornea. The instrument measures the anterior and posterior surface of the cornea by taking single slit images within one scan in less than two seconds while rotating from 0–180° to maximise the measured area of the cornea. Five hundred measurement points from each slit image is recorded, totalling twenty-five thousand (25000) true elevation points (HR model one hundred-and-thirty-eight-thousand [138000]). The centre of the cornea is finely measured during the rotation while the pupil camera detects eye motion which is corrected in the calculation process. An exact three-dimensional model of the anterior eye is then created. The topography and pachymetry of the entire anterior and posterior surface of the cornea, from limbus to limbus, are displayed and calculated. Unlike placido curvature measurements systems, topography maps are generated by true elevation data. The analysis also includes a calculation of the anterior chamber angle, chamber volume, chamber height, lens densitometry and manual measurements at any location in the anterior chamber of the eye. The Pentacam further calculates a quality specificity score (QS), which takes into account, the analysed area of the cornea front and back curves, alignment and ocular motion. This helps the clinician to assess the validity of the data in each examination [94, 95].

Although the Pentacam can be used to generate topography maps similar to that of the corneal topography systems it's much more powerful and provides numerous options to analyse the cornea which is beyond the scope of this chapter. Additional software can be purchased allowing even more specialised analysis of the cornea pre-operatively and post-operatively, contact lens fitting and crystalline lens densitometry. Included in the standard software package is a keratoconus analysis and grading system which is based on internationally accepted protocols. This will be discussed further under the chapter dealing with keratoconus.

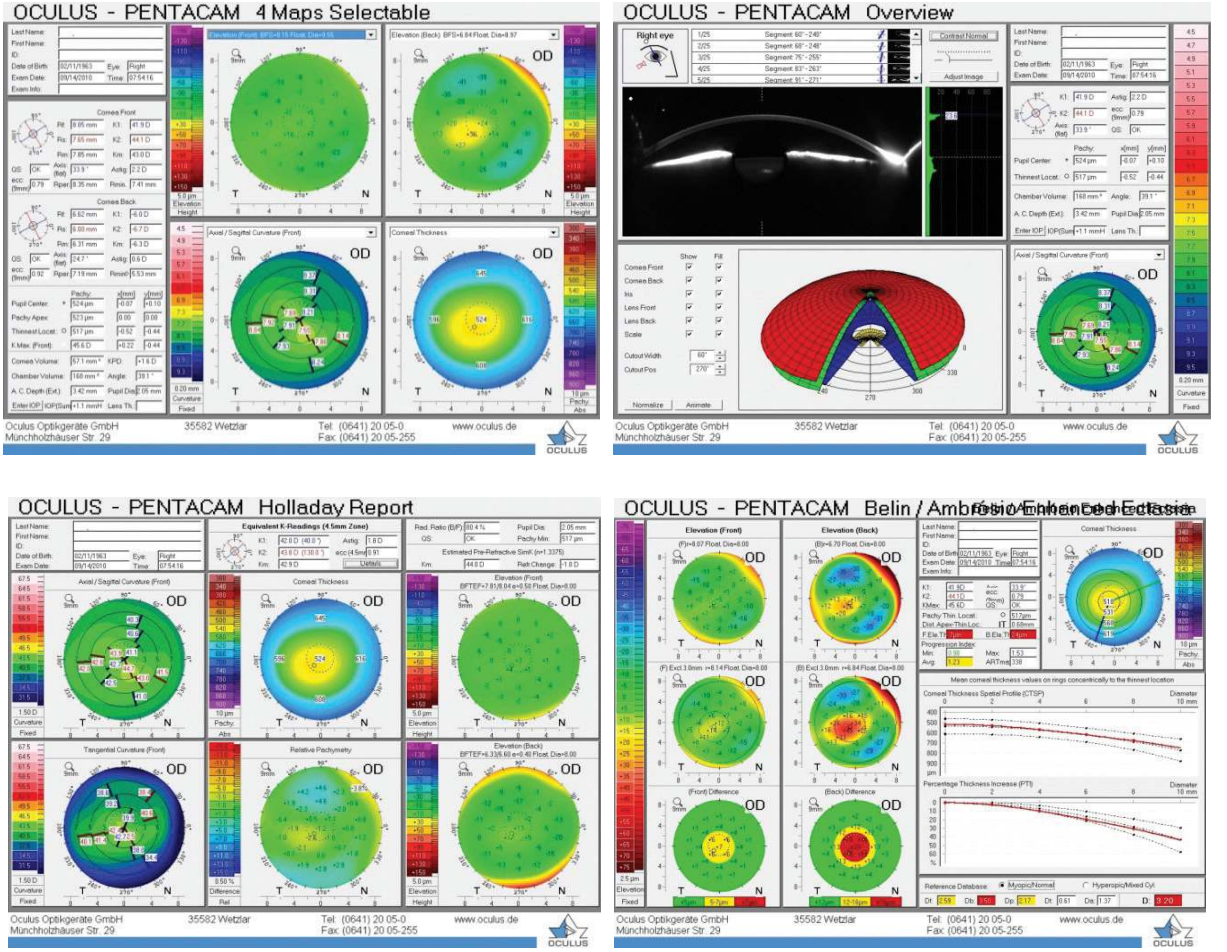

Figure 29: Diagnostic maps from the Oculus Pentacam system

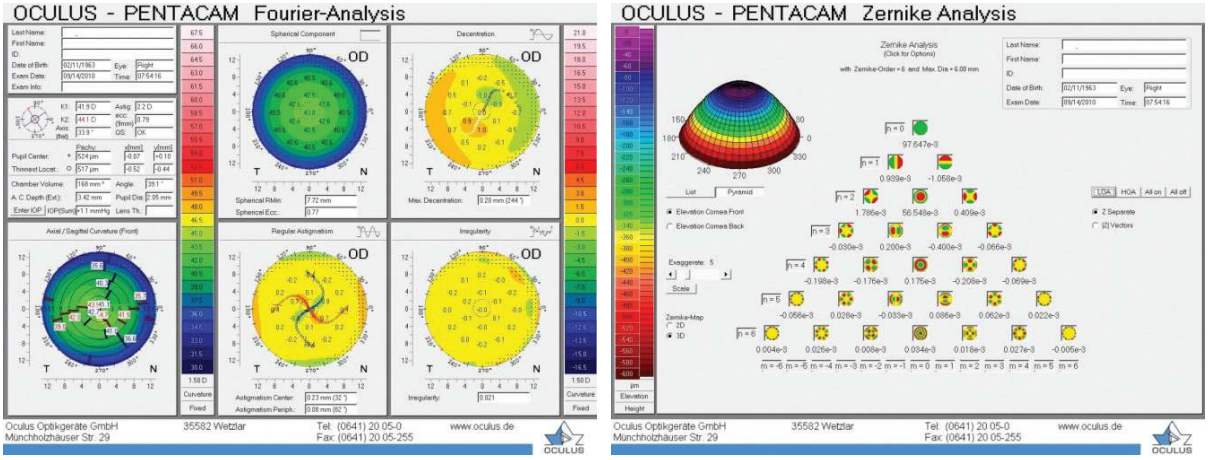

Figure 30: Higher order aberration maps from the Oculus Pentacam system

Anterior Segment Optical Coherence Tomography (AS-OCT) [96]

Optical coherence tomography (OCT) is a high resolution cross-sectional imaging modality initially developed for retinal imaging. OCT utilises near-infrared light waves to measure distances of anatomical structures. A beam of light is directed onto the structure and the echo time delay of light is then recorded. Employing low-coherence interferometry, the reflected light from the eye is compared to a reference value of a known length. A series of

axial scans (A-scans) are combined to form two-dimensional images of the ocular structures in a process similar to ultrasound biomicroscopy. However, light (as opposed to sound waves) is used in OCT. Cross-sectional images are then generated by scanning the incident optical beam. The resultant scans are displayed in a colour scale. AS-OCT imaging was first described in 1994 by Izatt et al. using the same wavelength of light as retinal OCT (830 nm). This wavelength is suboptimal for imaging the angle due to limited penetration through scattering tissue such as the sclera. OCT imaging of the anterior segment with a longer wavelength of 1310 nm was subsequently developed and had the advantages of better penetration through sclera, as well as real-time imaging at 8 frames per second. Several retinal Fourier domain (FD) OCT devices allow imaging of the anterior segment. However, they still use the shorter wavelength of 830–870 nm with its inherent disadvantages in imaging the AC angle. The higher resolution provided by FD retinal OCT devices does have advantages in imaging other structures in the anterior segment such as the cornea and conjunctiva. AS-OCT is widely applicable in the ophthalmic practice. Each platform allows imaging of the cornea, anterior chamber, lens and iris that can assist in diagnosing and managing anterior segment disease, refractive surgery, contact lens practice and glaucoma.

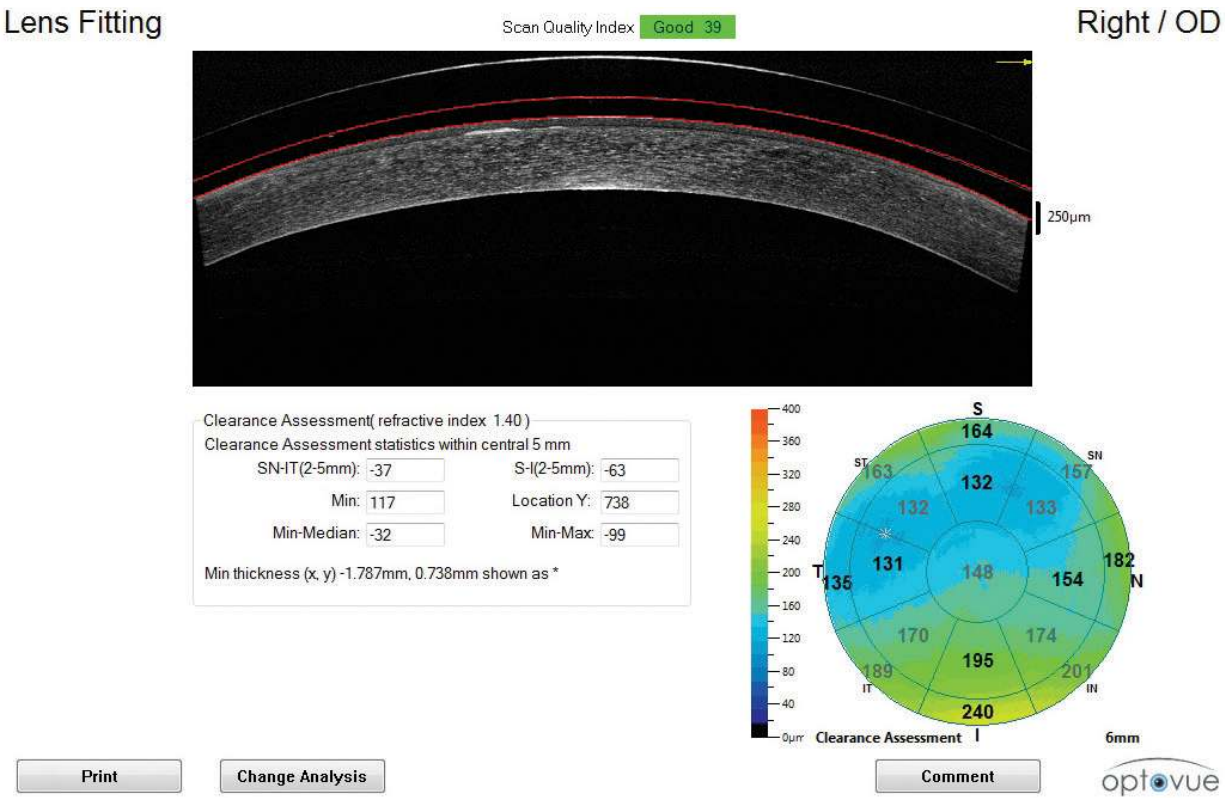

Figure 31: AS-OCT image (Optovue®) showing a mini-scleral lens in situ

Note the apical clearance map generated by the software (lower right).

Measuring the Sclera [97–99]

sMap 3D Topographer

The sMap3D topographer (Precision Ocular Metrology) uses a structured light approach, to obtain three-dimensional mapping and measurements of the cornea and sclera with a 22 mm maximum field of view. It measures over 1 million data points and has ±10 microns precision. The sMap3D takes multiple triangulated measurements, using a single DLP projector and two cameras positioned laterally on each side. Fluorescein is added to the patient's eye,

which is necessary for imaging the corneal and bulbar conjunctival surface. The patient is then instructed to gaze at a fixated light straight ahead while the eyelids are opened as widely as possible with assistance from the practitioner or a staff member. The practitioner focuses the eye and captures the image. Two additional measurements with the patient fixating up and down are taken in succession. The sMap3D software stitches together the images taken in straight, up, and down positions to produce a three-dimensional model of the patient's eye. Stitching is a necessary step to obtain maximum area of the sclera that is occluded by the lids despite the eyelids being held open. A stitched model is required for measurement of the vertical meridians to determine accurate toricity measurements and over all sagittal depth value, which are used for custom scleral lens fitting. The sMap3D software gives sagittal depth data at any specified chord. Corneo-scleral topography and elevation maps can be evaluated. Scleral toricity can also be calculated from any specified radius from centre.

However, while this instrument provides more information about the ocular surface than corneal topography, at the time of writing, it is so new that the data it provides cannot yet be applied universally to all scleral lenses with simple formulas or rules.

Eye Surface Profiler (ESP)

The Eye Surface Profiler (Eaglet Eye, Netherlands) is a new technology based on Fourier transform profilometry to measure the anterior surface of the eye, especially the corneo-scleral area. Sinusoidal gratings are projected onto the eye surface and their reflections are captured by a camera. The images are then processed with the help of Fourier transform methodology. To extend the measurement area beyond the corneal surface, fluorescein is instilled in the eye and the fringe pattern projectors emit blue light. To optimise image contrast, a yellow filter is added in front of the imaging device.

The 3D output data of the ESP is used to estimate simulated keratometry, corneal asphericity, corneal axial, tangential and refractive power and many other parameters typically found in videokeratoscopy software. Additionally, the instrument also measures limbal and scleral topography up to 20 mm with lid retraction. The accuracy of the ESP is reported to be similar to videokeratoscopy. However, while this instrument provides more information about the ocular surface than corneal topography, at the time of writing, it is so new that the data it provides cannot yet be applied universally to all scleral lenses with simple formulas or rules.

THE BURTON LAMP [88].

Traditionally fluorescein (NAFL) patterns were observed by using a Burton lamp. The Burton lamp consists of a UV lamp (300–400 nm) and +5.00D magnification. It is inexpensive and simple to use, allowing good overall and binocular views of the NAFL patterns. Its limitations include the fact that it does not have variable focus and that newer RGP material have UV filters which absorb UV below 400 nm, reducing the fluorescence.

VITAL DYES; FLUORESCEIN (NAFL), FLUOREXON, ROSE BENGAL AND LISSAMINE GREEN [100].

This is a yellow acid dye of the xanthene series and was first used on the eye in 1882 when researchers discovered that it could reveal corneal epithelial defects. When exposed to light, fluorescein absorbs certain wavelengths and emits fluorescent light of a longer specific wavelength. For dilute concentrations of fluorescein, light of wavelengths 530 nm produces the maximum intensity of fluorescence. Fluorescein is a weak acid and depending on the solution it can exist in various ionic states. Below pH 2, the cationic form predominates, and a weak blue-green fluorescence occurs. Between pH 2–4, the cations dissociate to neutral molecules. At pH 7, negative ions prevail and are associated with a brilliant yellow-green fluorescence.

Factors that alter the fluorescence are:

- Concentration, maximum at 0.001%
- pH of the solution, maximum fluorescence at physiological pH of 7
- Presence of other substances
- Intensity and wavelength of the absorbed light

Fluorescein in solution is highly susceptible to bacterial contamination, especially by *Pseudomonas aeruginosa*. *Pseudomonas* grows easily in the presence of fluorescein. Fortunately, the use of fluorescein impregnated sterile filter paper strips has been devised to eliminate the risk.

Due to the high degree of ionisation at physiological pH, fluorescein does not penetrate the intact corneal epithelium well nor does it form a firm bond with any vital tissue. From the ocular surface perspective, the water-soluble dye molecules diffuse into the intracellular spaces between the living cells. The intensity of the stain is increased in areas of cellular degeneration or death where the damage to cells, cell membranes, and cell-to-cell junctions allows for the intracellular spaces to be more highly penetrated by the dye. It is this property that makes the dye most useful for observing permeability in corneal epithelial and endothelial cells. In conjunctival epithelial cells, observation is made difficult by the dye's presence in both the cells and the intracellular spaces.

However, new evidence challenges the previously held view that corneal staining is caused by surface ingress around cells, or surface pooling and uptake by dead or damaged cells. Research has demonstrated that fluorescein molecules can enter and leave healthy and intact epithelial cells that concurrently demonstrate mitotic activity, indicating that the cellular metabolic activity remains normal despite cells being fluorescein "stained". Furthermore, daughter cells that contain fluorescein demonstrate healthy function. Lastly, there is evidence of fluorescein diffusion between adjacent cells. This research highlights the limitations of using fluorescein as an ambiguous tool for assessing the ocular surface health and calls into question the dogmatic viewpoints of corneal staining strictly representing corneal damage or injury.

SICS or solution induced corneal staining is characterised by asymptomatic and transient corneal staining associated with the use of multipurpose solutions (MPS). This phenomenon is typically seen 30 minutes to 4 hours after soft lens insertion and resolves after 6 to 8 hours depending on the specific combination of MPS and contact lens material. The intense appearance of SICS may indicate a solution induced corneal toxicity reaction. However, the lack of symptoms and the fact that the reaction lasts on average only a few hours is markedly different from a true toxicity reaction which is symptomatic and can take days to resolve. Concomitant signs such as limbal or bulbar hyperaemia and corneal infiltrates are also absent. Research has shown that MPS containing PHMB (polyhexamethylene biguanide) interact with fluorescein and the ocular surface leading to benign transient corneal hyperfluorescence (SICS) observed in MPS users. SICS can be dramatically reduced by applying a drop of rewetting solution containing carboxymethelcellulose.

Fluorescein is used in contact lens practice, not only to evaluate the anterior segment and lacrimal system of the eye, but also for evaluating the fitting characteristics of RGP and scleral lenses. As such it is an indispensable tool in contact lens practice. However, fluorescein can penetrate into soft contact lenses, discolouring the lenses and causing cosmetic problems. The boundary between the lens and the tears is obscured precluding the use of fluorescein in soft contact lens fitting.

Fluorexon, a molecule similar to fluorescein, has a molecular weight of 710M and is less readily absorbed by the soft lens material, making it more useful in fitting and evaluating soft and hybrid contact lenses. It is paler and yellow-brown in colour and its staining characteristics are similar to those of fluorescein, except that it will stain devitalised tissue. Fluorexon is vulnerable to bacterial contamination, supporting bacterial growth for longer than

a comparable fluorescein sodium solution. It will stain the soft lens if it remains in contact with the lens for more than a few minutes. However repeated rinsing with saline will remove the dye from the lens. Fluorexon is not recommended for use in highly hydrated soft lenses with a water content of 60% or higher. Significant dye can be absorbed in these lenses leading to lens discoloration.

Rose Bengal is a derivative of fluorescein. Both dyes are hydroxyxanthines. When viewed with white light, tissues stained with rose Bengal display a vivid pink or magenta colour. It is formulated as a 1% solution in the form of a sterile impregnated filter paper strip. Rose Bengal is a photoreactive compound. In the presence of 550 nm light and oxygen, a singlet oxygen molecule is generated. This can inactivate enzymes and damage single stranded DNA and cell membranes. Rose Bengal is cytotoxic and can kill microorganisms including herpes simplex-1 virus (HSV-1) and protozoa. It stains not only dead or dying cells as previously thought, and actually stains normal healthy living cells as well. The dye localises primarily in cellular nuclei and to a lesser degree in other organelles.

How then do we explain its selective staining in dry eye or Sjörgen's syndrome? It turns out that Rose Bengal is blocked from staining the ocular surface where molecules such as mucins, albumin or even artificial tear compounds such as carboxymethylcellulose are present. Rose Bengal penetrates the ocular surface in areas where there are breaks in the tear film integrity or a dysfunction in the production of the tear film components. Rose Bengal can therefore not be termed a "vital stain". Lastly, it is widely known for patient discomfort particularly stinging on instillation, which can become quite severe and is often a deterrent from using Rose Bengal. It will stain skin, clothing and contact lenses. Due to its antiviral and antibacterial properties, the use of Rose Bengal may cause a further dilemma if a culture is needed for diagnosis. Rose Bengal is difficult to obtain in South Africa.

Lissamine green B has been known by a variety of names: Wool Green S, Food Green, Acid Green S, Fast Light Green, Pontacyl Green S, Cyanol Green B, Calcoid Green S extra and Pyronin G. Unlike the hydroxyxanthines previously discussed, lissamine green is classified as a phenyl methane dye. It is widely used as a non-ophthalmic drug and cosmetic food additive. It is available as a 1% individually packaged filter paper strips. Lissamine green preferentially stains membrane damaged or devitalised cells and localise in the cell nucleus. It does not stain healthy, proliferating ocular surface cells and has a minimal effect on cell viability. It has no carcinogenic or cellular toxicity properties. There is no stinging or discomfort with topical administration. In red eyes, due to the contrast, the visibility of the dye is enhanced, quite unlike the pink colour of Rose Bengal which may be somewhat masked. The vital dyes, fluorescein or fluorexon and lissamine green complement each other. Fluorescein staining between the devitalised cells indicating areas of greater permeability and the lissamine green staining the devitalised cells which then appear particularly clearly on the conjunctiva. The use of these vital dyes greatly enhances the diagnostic ability of the eye care professional.

EXAMINING THE TEAR LAYER [48, 49, 88, 101, 102]

From the discussion in chapter 2 it is evident that the tear layer is a very complex structure and is affected by the presence of a contact lens on the eye. It is therefore important to evaluate the tear layer before fitting a contact lens on the eye as well as at every follow-up visit to ensure comfortable and complication free contact lens wear. The different tests available to evaluate specific characteristics of the tear film are listed in Table 14 with their normal values. Generally, these tests evaluate the quantity and quality of the aqueous part of the tear film, the stability of the mucus layer and integrity of the lipid layer. Although important, some of the tests are beyond the scope of normal practice and will therefore not be discussed.

Quantity of Tears (Lacrimal and Accessory Glands)

The tear meniscus gives a good indication of the tear volume and is readily visible with the slit lamp. Normally, the meniscus on the bottom lid should be between 0.1–0.6 mm high. The phenol red strip gives an indication of the quantity of the tears. The test consists of a two-ply thread impregnated with phenol red dye. The thread is pH sensitive and changes to yellow when wetted by the tears. The thread is folded at 3 mm and this end is inserted into the lower fornix **before anaesthetic** is applied to the eye. Normal wetting values are 10–20 mm in 15 seconds. The Schirmer test is similar in nature but more uncomfortable due to the size of the filter paper inserted into the lower fornix. Schirmer 1 test is done without topical anaesthesia and have little clinical value due to the discomfort and resulting reflex tear secretions. Schirmer 2 is done **after anaesthesia** and normal wetting values are > 15 mm after 5 minutes.

Quality of Tear Film and The Mucus Layer (Conjunctival Goblet Cells, Corneal Epithelium Glycocalyx and Lacrimal Gland)

Tear break-up time (TBUT) with fluorescein or non-invasive tear break-up time (NITBUT) with the Tearscope (Keeler, UK), Oculus Keratograph (Oculus, Wetzlar, Germany) or keratometer mires, can be used to evaluate the tear film stability. TBUT is recorded when the first streaks appear in the tear film containing the fluorescein. The Tearscope (Keeler, UK) uses a cold light source to minimise any drying of the tear film during the examination. It can be used directly in front of the eye or in conjunction with a slit-lamp to gain more magnification. Evaluation of the interference patterns of the anterior surface of the tear film lipid layer facilitates the diagnosis of the cause of dry eye symptoms and screens patients for contact lens wear. The instrument also allows the measurement of the non-invasive break-up time.

Another simple test of tear film stability can be done by having the patient look at the Snellen chart with spectacle correction using a 6/9 line of letters. The patient blinks and keeps his/her eyes open and the time to first blur is recorded. This normally occurs when the tear film loses stability.

The ratio between the TBUT and the blink rate (inter-blink interval) defines the ocular protection index (OPI). It can be mathematically expressed as follows OPI = TBUT/Blink Rate. The ocular surface is considered to be protected when the TBUT matches or exceeds the OPI, in other words OPI ≥ 1. When the TBUT is less than the blink rate (OPI < 1), or the blink is incomplete the ocular surface is not protected, and the patient is at risk.

Ocular Surface Assessment

The surface integrity can be assessed by the different staining techniques and vital dyes discussed before. Fluorescein highlights the loss of epithelial cells and consequently, loss of the ocular surface integrity. Lissamine green and Rose Bengal determine cell vitality.

Impression cytology is a histological evaluation of biopsy samples taken from the ocular surface using filter paper. This tissue sampling is useful in assessing conjunctival health and the severity of a dry eye condition.

Table 14: Most common tear function tests and their normal values [5]

Test	Significance	Normal values
Limbal hyperaemia	Ocular irritation	Grade 0
Tear meniscus	Aqueous quantity	0.1–0.6 mm
Phenol red thread (Zone quick)	Aqueous deficiency	> 20 mm in 15 seconds
Schirmer 2	Aqueous deficiency when reduced	> 5 mm in 5 min

Contd…

Test	Significance	Normal values
TBUT	Tear film stability / mucus deficiency	> 10 seconds
NITBUT	Micro epithelial defects / aqueous adequacy	30 seconds
Fluorescein staining	Micro epithelial defects / mucus deficiency	Grade 0
Rose Bengal, Lissamine Green	Non-mucus coated epithelium	Grade 0
Meibography	Morphology of Meibomian glands	Linear non-distorted dark areas of acini
Meibomian gland expression	Meibomian gland function	Clear
Schirmer 1	No diagnostic value	> 15 mm in 5 min
Tear osmolarity	Lacrimal gland function	280–318 mmol/kg
Impression cytology	Epithelial cell appearance/ goblet cell density. Squamous metaplasia seen in dry eyes.	Normal microscopic appearance
Lactoferrin	Lacrimal gland function. Decreased in dry eye conditions	> 0.9 mg/ml
Tear IgE	Lacrimal gland function. Increased in dry eye conditions	50–60 ng/ml
Interference fringe pattern	Lipid layer integrity	Uniform slit-lamp appearance

Instrumentation and technology has certainly made a clinician's life a lot easier than in years past. Measuring the shape of the cornea and sclera is now almost routinely done using corneal topography and Scheimpflug systems in nearly all practices. Although these instruments are extremely accurate and relatively easy to use they are also prone to errors especially due to misalignment, fixation, blinking and dry eye problems. The software is unique to each instrument and can be setup by the clinician to suit his/her needs. Unfortunately, very little instrument specific training is available in South Africa and practitioners are often left to figure things out on their own which results in the underutilisation of an expensive piece of technology. With the more advanced analysis systems, such as the Pentacam, additional software is often available for specific analysis. It may take months or even years of work with the system to fully realise its potential. I don't advocate the use of the contact lens fitting programs but many of my colleagues use this function with success. My advice is therefore to invest wisely (rather spend a bit more and get a Scheimpflug system than a topographer), get decent training, attend information sessions at conferences and make the instrument part of your comprehensive examination of each-and-every patient you see.