THE SLIT LAMP
BIOMICROSCOPE

in Optometric Practice

An essential guide for optometrists and students of optometry

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SLIT LAMP BIOMICROSCOPES are used by Optometrists routinely these days and, together with suitably qualified Dispensing Opticians, for contact lens work.

Whether patients come for a routine eye examination or whether they arrive as an ‘emergency’ for advice about conjunctival redness, their contact lenses or a foreign body in the eye, the Optometrist should have the equipment to be able to examine the eyes for any ocular changes which may have occurred. The ophthalmoscope enables most corneal irregularities to be observed, but small abrasions, particularly if near the limbal region, can easily be missed with an ophthalmoscope and with ordinary focal illumination and loupe, but not with a slit lamp biomicroscope. Removal of superficial foreign bodies is carried out more easily by observing through the biomicroscope while the removal is done; as is epilation of aberrant eyelashes.

Untoward changes due to wearing contact lenses of any material can occur in the relevant structures of the eye and can only be satisfactorily detected at an early stage, if a biomicroscope is used. All conscientious practitioners, for their patients’ benefit and for their own benefit (from a legal standpoint) must, therefore, use a slit lamp.

A slit lamp has become a necessity for the careful observation of the fit of contact lenses both initially and during aftercare.

Slit lamps are a significant investment in terms of equipment and to use them to their fullest advantage, a routine method is desirable, as well as much practice.

**History**

Practical slit lamp work became an important part of the ophthalmological examination over 100 years ago, when the Nernst line filament lamp was developed and Gullstrand’s projection system was used. With the advent of coiled filaments, it became necessary to project an image of an illuminated slit aperture on to the eye, rather than the image of the lamp filament. The projection system employed by Vogt has been used in its original form, or somewhat modified form since then.

From the original instruments, which had independent illuminating and observing systems, slit lamps have progressed to the stage where the two systems are coupled and they have become precision instruments of high quality (see Figure 1).

**Instrument Details**

The slit lamp (or biomicroscope) enables the practitioner to make an optical section through the transparent structures of the eye and observe these and the other non-transparent structures with a binocular microscope. The latter permits a magnified three dimensional view of the ocular tissue.

It is essential that the slit lamp beam is of even illumination and has sharply demarcated edges. If not, irregularity of the beam may be interpreted falsely as irregularity of the tissues.

Eyepieces are parallel or convergent. Some observers have doubled images when working with parallel eyepieces - so convergent binocular tubes will give a more relaxed view in those cases. Some new instruments have convergent eyepieces, but parallel optical paths.

The illumination system is basically a short focus projector. Not only can a narrow slit beam be projected on to the eye, but also any shaped patch from a slit to a circle and of varying sizes. Some form of rheostat or illumination control is usually incorporated and frequently, the lamp housing is rotatable to allow the slit to be used in meridians other than vertical. Coloured filters, usually blue and green (redfree), are normally available, and so are diffusers. The yellow Wratten 12 filter can be placed in front of the objective when needed.

Polarising filters are sometimes provided in both illuminating and observing systems to cut out specular reflections. Thus, the instrument is not restricted to viewing slit sections, but all the external eye structures can be studied, as well as some of the internal ones.

Hand slit lamps are still useful for examining anterior chamber depth and for observing the media under low magnification, but if high magnification is to be used, a hand-held instrument is not satisfactory as any small movements are also magnified and the area under observation is apt to move right out of the field of view.

**Controls and Focusing**

In routine use, modern instruments ensure that the tissue being illuminated is clearly seen by having a common focus for the beam and microscope. Further, both microscope and illuminating system can be swung around this focus position, so that the tissue focused can be viewed and illuminated from any direction in front of it. This is achieved by arranging that the supporting arms of both the microscope and illuminating system rotate about a point immediately below their common focus.

A height control usually moves both systems together, and focusing and lateral movements are common to both - joystick control is normally employed. This common control facilitates quick positioning of the beam on to the appropriate part of the eye, and by
An against movement of the slit indicates that the illuminated area is beyond the focus position, i.e. too far away from the observer. An appropriate movement of the joystick may then be made to bring the slit to its true focus, which can then be viewed and checked through the microscope.

**Method of Use**

*Magnification and viewing in general:*

Magnification of 6x to 40x is usual and obtained by varying the eyepieces and objectives of the microscope. Some instruments have a zoom lens magnification system which is a delight to use. It should be noted that magnification of 40x or more is essential to observe the more subtle changes in ocular tissues now better understood to be induced by contact lens wear (e.g. microcysts).

**Stains**

To aid observation of damaged or abnormal tissue, sodium fluorescein 1% or 2% and Bengal rose 1% may be instilled - the latter is best seen using white light, and fluorescein stains can also be seen thus, but blue light does increase the contrast. Before instilling Bengal rose, the rest of the eye's surfaces should be viewed after instilling fluorescein. This is because Bengal rose may cause superficial punctate staining with fluorescein, if it is applied too liberally.

The instillation of fluorescein is best done by means of a fluorescein impregnated paper strip (e.g. a Fluoret™), which should be wetted, preferably with sterile saline. Other suitable solutions such as an eye-irrigating solution, or one of the proprietary contact lens soaking or rinsing solutions which are compatible with the ocular tissues, can be used but they must not be too viscous. On no account should tap water be used, for potentially harmful organisms are not uncommon in tap water (e.g. pseudomonas aeruginosa, acanthamoebae etc.). Owing to the risk of scratching the cornea with the wetted strip, it is best to ask the patient to look upwards and apply the wetted strip to the bulbar conjunctiva below the cornea, or into the lower fornix. Then, should the patient blink or Bell's phenomenon occur (when the eye turns upwards), there is no risk of the cornea being damaged by the paper strip. With most, but not all, regular contact lens wearers, fluorescein may be applied safely to the upper bulbar conjunctiva with the patient looking down. If there is any likelihood of cross-infection from one eye to the other, a separate fluorescein strip should be used for each eye.

If excess fluorescein is instilled, the tears film in front of the cornea becomes green with fluorescein and this may mask any small abrasions of the corneal epithelium. Staining of the corneal epithelium may be caused by mechanical damage, chemical injury or as part of an allergy or an eye infection syndrome, either local or systemic. It may be necessary to wait a few minutes or so to allow the excess fluorescein time to drain away into the nose, or it may be washed away by the instillation into the conjunctival sac of several drops of normal saline (e.g. from a Minim™) or other irrigating solutions such as 2% sterile sodium bicarbonate solution.

**Tears Break up Time**

However, if contact lenses are to be fitted, this fluorescein film may be made use of to estimate the provoked tears film break-up time (TBUT). A wide blue beam is used to illuminate the tears film and after a single complete blink, the patient is instructed to keep the eyes open, and the number of seconds before the tears film begins to break up is recorded. This time is said to be related to the functionality of the tears and their relative watery content. The TBUT should be greater than 10 seconds. There are limitations to using the TBUT as an absolute guide, because the fluorescein challenge destabilises the tears film, the volume of the fluorescein drop relative to the volume of the tears, and the humidity and temperature of the consulting room have a significant influence on the result. The important aspects are the presence of a break in the film within the normal interblink interval and the position at which it occurs. Whatever the TBUT is in seconds is only relevant when compared to the time between normal blinks and, if the tears film breaks at the same point each time, the incidence of epithelial desiccation in that area will be higher. If TBUT is repeatedly low, it is probably inadvisable to measure the non-invasive tears film break-up time (NIBUT), or otherwise, only proceed with caution. Soft contact lens wearers having a low tear film TBUT get a great deal of mucus build-up on their lenses which consequently needs very frequent cleaning and replacement. Wearers of hard lenses with low TBUT also tend to get greasy problems with their lenses. The watery content of the tears may be affected by certain systemically used drugs such as steroids and beta-blocking agents.

It should be noted that if a patient is in a debilitated condition, due to a recent illness or head cold, then the cornea may be more permeable than usual and absorb a slight amount of fluorescein which shows up with the slit lamp as a diffuse green haze. Abrasions and local anaesthetics also increase the permeability of the cornea so that the fluorescein may pass into the anterior chamber 10 minutes or so after its instillation. The use of the Wratten 12 filter enhances the visibility of any staining on the cornea. This is a deep yellow filter which can be hand held or
may be incorporated in more modern instruments. As it is a blue-complementary filter it makes any staining show up much more definitely when used with blue light and fluorescein.

The other useful staining agent to apply before examination with the slit lamp is 1% Bengal rose (also available in Minims). Mucus and dead epithelial cells take up this red stain. It may be applied to the eye in the same way as fluorescein, but to avoid any stinging, the vital stain can be poured on to a cotton wool bud and applied to the eye by a touch on the bulbar conjunctiva. If patches of bright red staining of the corneal or conjunctival epithelium occur, then the eye is/may be suffering from a dry eye condition which would benefit from a more detailed dry-eye evaluation.

It is normal for each lid margin to be lined with a thin strip of mucus which stains red with Bengal rose, and this may become detached as the lids are manipulated forming a red string of mucus on the surface of the eye.

During normal blinking, lipids and/or conjunctival mucus are spread over the surface of the cornea and rubbed in between the superficial epithelial cells by the rubbing action of the eyelids. By lowering the surface tension, this enables the corneal surface to retain the watery element of the tears film, which is then hindered from evaporating by a surface oily layer. In a normal eye, when Bengal rose is instilled, it does not stain the superficial cornea or conjunctiva. But, if for some reason, the eyelids are prevented from rubbing the corneal surface during blinking, the lipid layer which normally adheres to the surface epithelial cells is not deposited. This in turn prevents retention of the watery layer, so that in those areas where the cornea is exposed to the atmosphere, it tends to dry out.

Where the surface epithelial cells dry up and die, the epithelium will then take up Bengal rose stain. Typically, elevations of the conjunctiva near the limbus region such as pingueculae and pterygia, as well as the wearing of corneal contact lenses with thick edges and/or too much peripheral clearance, prevent the eyelids from rubbing the necessary mucus/lipids into the peripheral cornea. As it is the three and nine o'clock areas of the cornea which are exposed most to the atmosphere, it is these areas which most frequently stain with Bengal rose.

Where there is reduced tears output, as in Sjogren's syndrome, and the eye is very dry, filaments of dead epithelial cells gradually detach from the cornea and bulbar conjunctiva and take up the red Bengal rose stain.

### Tears Prism

The tears prism regularity and height give a good indicator of the state of the tears film. Its height can be assessed using the beam in the horizontal position and measuring with the width indicator. A low tears prism or gross irregularity indicates a quantity and quality problem whilst simple notching shows a meibomian gland dysfunction.

### Routine and Methods of Illumination

Every regular user of a slit lamp gradually develops his or her own routine for operating the instrument and examining the eye, until handling the instrument controls becomes automatic - rather like driving a car. For the guidance of those unused to the operation of a slit lamp, the following routine should prove useful and serve as a sound basis on which a more elaborate technique may be built later.

Before switching on the instrument, make sure that its vertical control is in the middle of the travel range, to allow for movement in either direction later. Adjust the table height, the chin rest height and the chair height of both patient and operator so that the examination can be carried out in comfort. This always saves time in the long run. Many patients are somewhat apprehensive at the sight of a large instrument and it is, therefore, as well to reassure them about its use beforehand, stating that it is only a bright light and a microscope. A co-operative patient is much easier to examine than a frightened one! Instruct the patient to keep their forehead against the rest, and make a final adjustment on the chin rest height so that the eyes are at the required level. This level is marked on the head rest supporting columns of most modern instruments and is usually an engraved or indented ring.

First adjust the eyepieces of the microscope and their separation to allow for any refractive error and the interpupillary distance respectively. Then position the microscope so that it is in front of the patient's eye with the illuminating system at about 60° to it, on the temporal side. With the patient's eyes closed, switch on the instrument with the rheostat set in the centre of its range. Without looking through the microscope, focus a vertical slit on the lid surface using the joystick control and moving the slit beam supporting arm about its centre of rotation, as described in Instrument controls and focusing (see Figure 2). Use a beam width of ½mm to 1mm and with a magnification of 6x to 10x, check the focus through the binocular microscope.

Instruct the patient to open their eyes and stare straight ahead. If a fixation target is provided, this may be used for the other eye in order to control eye position. Then observation of the eye by the various different methods of illumination may be carried out.

### Diffuse Illumination

If a diffuser (ground glass filter) is available, put it in place before the beam and study the external eyes as a whole (lids, lid margins, puncta, lashes, plica, caruncle, bulbar conjunctiva, limbus and cornea, and for contact lens work, the tarsal conjunctiva). Increase the magnification if anything of particular interest is seen, e.g. pronounced limbal blood vessel loops. Illumination may be increased by using the slit width control and/or rheostat. Then return to low magnification, and a fairly narrow beam of 1mm.

### Sclerotic Scatter

Without looking through the microscope, which may be temporarily moved to one side, remove the diffuser and move the beam to the temporal limbus, and examine the cornea from directly in front. It is essential that this technique is carried out in a totally darkened room. Light from the focused beam at the limbus is totally internally reflected by the cornea, but scattered by the sclera which, therefore, glows all around the limbus (see Figures 3 and 4). The normal cornea should
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Figure 4
Central corneal oedema (central circular clouding) seen from in front as shown up by scleral scatter.

Figure 5
Direct/Focal Illumination
The slit lamp and the beam are focused at the same point

Figure 6
Diagram of a parallelepiped section showing the bright surface of the tears and less bright endothelium.

appear dark, but any irregularity or opacity of the corneal tissue will interrupt the total internal reflection and scatter the light, rendering that portion of the cornea visible against the dark background of the iris, as in Figure 4. With this technique, a general picture is obtained without the microscope. For example, marked oedema is easily seen without a microscope, but slight amounts may only be visible by moving the head about and looking at the cornea from several angles of view or by viewing through the microscope. For viewing through the microscope, the area of tissue must first be located and focused using the direct method of illumination, and then the beam uncoupled and directed to the limbus.

Direct illumination.
This means that the observer looks directly at the focused beam, whatever its size and shape. A 2 mm wide slit allows a parallelepiped section of the cornea to be viewed, which permits surfaces as well as the stroma to be studied (see Figures 5 and 6).

Generally, a very wide beam is used for surface study and a very narrow beam for sections. The parallelepiped section is a useful combination of the two, permitting the scanning of any interesting feature. This could be in the cornea, aqueous, crystalline lens or vitreous. Direct illumination is the most common method of viewing all the tissues of the anterior eye and adnexa. (Diffuse illumination may be considered as one form of direct illumination).

To view the cornea in detail, use a beam width of 2 mm and a magnification of 10x to 25x at first. Focus the instrument, by means of the joystick, on the limbal blood vessels. This allows the front surface of the cornea to be kept in focus from the start. Then move the beam laterally towards the apex of the cornea with the beam at about 45° to 60° to the temporal side and the microscope directly in front. Encourage the patient to blink occasionally, as this not only prevents drying of the cornea, but also allows the epithelial surface to be kept in focus as particles of dust and debris in the tears film can be seen to move up and down. To view the nasal side of the cornea, swing the beam round to a position about 45° to 60° to the nasal side of the microscope, and continue to move laterally until the nasal limbus is reached. This enables the cornea to be examined across its central area as well as the nasal and temporal limbus regions.

The normal epithelial surface presents a greyish, slightly granular appearance due to its cellular nature. This granular appearance is often more marked in contact lens wearers. Any damaged areas will have stained green with fluorescein and will show up against the light grey background. These areas should be examined with a magnification of 40x or more to be seen in detail, and the use of a cobalt blue filter will enhance the contrast between the fluorescein stained areas and the background. Whilst using the direct method of illumination, other observations should be made.

Optical Section
If any abnormality is found in any of the media, its precise depth is most easily determined by viewing an optical section, using as narrow a beam as possible (see Figure 7). It is usually necessary to reverse the positions of slit and microscope so that the slit beam is projected from in front and the observer views with the microscope set to give high magnification, from the side. When viewing the cornea in optical section, an angle of 90° between slit beam and microscope is possible but when viewing the crystalline lens or vitreous, the maximum angle between the two systems is determined by the size of the pupil and the depth of the tissue to be observed.

Specular Reflection
This can be used during direct observation by suitable arrangement of the beam and microscope. The out-of-focus image of the
slit formed by the corneal surface acting as a mirror is called the 'zone of specular reflection'. The quality of the reflection formed gives an indication of the quality of the surface from which the light is reflected. In this way, the cellular nature of the rear corneal surface can be studied with the out-of-focus second Purkinje image, formed by the cells of the endothelium, as a background. Holden and Zanto's have photographed the corneal endothelium in this way using very high magnification and have demonstrated the endothelial changes which take place with age and during contact lens wear. Fine detail of the individual endothelial cells is only possible to see on very enlarged photographs. A very irregular front corneal surface, seen by specular reflection against the very bright first Purkinje image, may well look rather like the surface of the moon! The appearance is most dramatic. It shows up well when the front corneal surface has become dimpled due to indentation by small bubbles under a contact lens. To reduce the glare from specular reflection off the front surface of the cornea, it helps observation considerably if a light blue filter is used, but this usually cuts down the illumination too much when viewing the lens surfaces and back of the cornea.

The front and back surfaces of the crystalline lens may also be studied in this way using the out-of-focus third and fourth Purkinje images as a background. To see the back of the crystalline lens in this way, the angle between the beam and microscope needs to be about 5°. When setting up the instrument to view by specular reflection, theoretically the angle of incidence equals the angle of reflection and so you need to set the beam and microscope at equal angles, but on opposite sides of the normal to the portion of surface being studied (see Figure 8). In fact, in practical terms for the cornea it is far simpler to have the microscope set in the straight ahead, position with the slit beam set to either side of the biomicroscope. With the patient looking straight ahead the beam is moved gradually towards the central cornea until one gets a very bright specular reflection from the tears film. Having observed the quality of this zone, one can then focus back to the endothelium where the small golden area of the endothelium mosaic is seen'. The specular image is only observed in one eye piece at a time, therefore there are two positions temporarily and two positions nasally of the zone with this method, all of which gives adequate viewing of the endothelium. In this way, this method of illumination can easily be incorporated into the procedure of direct illumination of the corneal tissue.

Mire Traverse

If, instead of focusing on the surface of the cornea or crystalline lens and viewing the surface against the bright background of the respective Purkinje image, the actual Purkinje image itself is focused by the microscope, then the quality of this image can be used to study the quality of the surface from which it is reflected. This is rather like judging the front surface quality of the cornea according to the state of the mire images seen by keratometry, allowing small irregularities and distortions to be detected by virtue of the mire image irregularity. Unless a diffuser is being used, the Purkinje image focused in this way is an image of the lamp filament, otherwise it is a reflection of the bright rectangle of the diffusing screen. In either case, this mire may be traversed across the respective surface to study its quality. The first, third and fourth Purkinje images are easiest to observe, the second being much more difficult to locate - very close to the first. To distinguish the third and fourth, the fourth - being formed by the concave reflecting surface of the back of the crystalline lens - gives an 'against' movement as the illuminating beam is swung from side to side, whereas the third is somewhat larger than the fourth and gives a 'with' movement. The first, of course, is the brightest and easiest to see.

Indirect Illumination

This means looking at the tissue outside the light patch. Once an interesting feature has been located by direct focal illumination, it may be viewed by indirect illumination by uncoupling the beam and moving it slightly to one side. This has the advantage of reducing glare. But when looking through the microscope with the beam normally coupled, the illuminated area does not fill the field of view, so that anything which reflects or scatters light back to the observer from an area beyond the illuminated slit patch is being viewed by indirect illumination anyway. Irregularities, such as dimples and bedewing as well as opacities, are most easily spotted in this way (also corneal nerve fibres and limbal loops), so that attention should always be given to the whole field of view and not just the region illuminated by the slit. This is shown in Figures 9 and 10. Oscillatory movements
of the beam assist in showing up regions of reduced transparency, as they are viewed in rapid succession by the direct and indirect methods. The term ‘indirect’ implies that the area observed is illuminated by light scattered or reflected from elsewhere (usually from the adjacent illuminated area - such as in sclerotic scar which is a form of indirect illumination) but sometimes from behind as now described.

**Retro-illumination**

This is where a tissue, usually the cornea, is viewed against a brightly lit background, usually the iris, as in **Figure 11**. Retro-illumination can also be used during observation by direct illumination by looking to the side of the beam where the light is hitting the iris. All three methods (direct and indirect and retro) are usually used without conscious effort to use one or the other.

However, retro-illumination is assisted if there is independent focusing of the microscope, so that the microscope can be focused in front of the slit beam; the same effect can be achieved where the beam can be uncoupled and offset to one side 6. Direct retro-illumination is where the light is directly behind the abnormality under observation which usually shows up as a dark circle with a light cenffe. It can also be used to detect abnormalities rather than confirm their existence. Once the light on the iris is moved so that the patch is half visible through the microscope, it is important to hold the joystick still for the seconds it takes to swing the beam so that the central corneal area is not missed.

For general observation, the microscope of the slit lamp is used from more or less directly in front of the patient, and the illuminating beam is placed to one side at varying angles to the microscope and patient as described. The exception to this is when viewing slit sections, which are often best illuminated from in front and viewed from the side through the microscope.

**Low magnifications are best to start with, increasing when something of interest is found which needs to be seen in greater detail, or if some very minute structural change is sought.**

**The limbus region presents many interesting features including capillary blood vessel loops which just enter the cornea, and the cessation of the myelin sheaths of the radially arranged nerve fibres, after about 1 mm to 2 mm penetration of the cornea. Normal signs of arcus are often seen, even in teenagers. This starts at the top and bottom of the cornea and, with age extends all round and widens. Provided that there is a clear band of cornea between the arcus and the limbus, then the condition is not pathological but it has been suggested that early signs of arcus in the under 35 age group are due to the deposition of cholesterol in the cornea and that this may indicate the parallel deposition of cholesterol in the blood vessels which is likely to lead eventually to coronary artery disease.**

*Often Schwab's line (where the corneal endothelium ends adjacent to the anterior chamber angle) is visible on the back of the cornea as a white diffuse line parallel to the limbus. It becomes visible in this way when the endothelium terminates in a tag of tissue extending back into the anterior chamber when it is known as posterior embryo-toxon or -toxin. If there is a complete ring visible round the entire limbus, then there is much greater risk of angle closure glaucoma and gonioscopy should be undertaken.*

During observation of the front corneal surface by means of the parallelepiped section, slight changes of focus enable the deeper layers to be studied. Any annoying specular reflections may be avoided at this stage by changing the angle between the two systems, or by using the polarising filters (if available). Following soft lens wear, vertical striae should be looked for. These are very fine wrinkles at the back of the cornea, usually approximately vertically orientated, and somewhat finer in appearance than corneal nerve fibres, a few of which can usually be seen traversing the cornea. The striae are thought to be due to the elasticity of Descemet's membrane permitting a slight buckling of the rear surface of the cornea as it swells backwards towards the anterior
chamber, and has to wrinkle in order to occupy a smaller area. Because soft lenses cover the entire cornea, it swells and the striae may be seen anywhere on the posterior one third of the stroma, but more frequently near to the centre. This is totally unlike the central circular clouding which is the manifestation of the forward swelling of the cornea following hard (usually PMMA) corneal lens wear.

**Other Observations**

While using an optical section, the anterior chamber may be scanned. The aqueous should appear optically empty, as it normally contains no cellular material to give rise to reflections or scatter (due to Tyndall's phenomenon). If flare (an increase in protein content of the aqueous) is encountered, a beam of circular aperture aids observation by illuminating a larger area of aqueous. Pupillary remnants commonly float in the aqueous and can usually be traced back to the iris collarette. They are almost always associated with one or more pigment stars on the front surface of the crystalline lens, and occasionally with pigment deposits on the rear surface of the cornea.

Of tremendous value is the technique of using an optical section to assess the degree of 'openness' of the anterior chamber angle. This was first described by Van Herick, Shaffer and Schwartz in 1969, and again by Polse in 1975. It consists of viewing with the microscope at low magnification (6x or 10x to give adequate depth of field) an optical section of the cornea, aqueous and iris, as near to the limbus as this can be obtained. The beam is set at 60° to the side of the microscope and the observation is made on the temporal side and on the nasal side. Throughout, the patient views the microscope, which is placed directly in front, although for viewing the nasal limbus, it may have to be rotated slightly temporally. The narrowest possible slit beam is traversed from the sclera on to the cornea at the limbus until an optical section is just visible. Then, a careful assessment is made of the ratio between the distance (along the incident beam) from the iris to the back of the cornea compared to the thickness of the cornea. A ratio of aqueous interval to corneal thickness of 1:1 (or more) indicates a wide open angle (Grade 4 according to Shaffer’s gonioscopic classification). A ratio of 1:2 corresponds to Grade 3, of 1:4 corresponds to Grade 2 which is narrow and should be viewed by gonioscopy as it is capable of closure, and if the ratio is smaller than 1:4, the angle is dangerously narrow (Grade 1) and likely to close. By looking at the nasal and temporal aspects of the angle, a good average is viewed, for the angle is normally narrowest at the top and widest open at the bottom.

Van Herick et al., found a very high correlation between these findings and gonioscopic findings. It is quickly and easily carried out and so it should be done routinely on all patients likely to become susceptible to narrow angle glaucoma. It should be noted that the technique is easier in those with brown irises than others, for the brown iris has a very smooth front surface, whereas blue and grey irises are irregular which makes the aqueous interval more difficult to assess in comparison to corneal thickness. However, the narrower the angle becomes, the easier it is to judge the ratio. Ratios of 1:4 or less indicate the need for referral for ophthalmological advice.

**General Observations**

Direct illumination of the iris surface and front surface of the crystalline lens allows observation of the iris pattern and orange peel effect, respectively. In light irides the radial blood vessels of the iris may be observed. Marked differences in the level of the surfaces of these tissues are noticeable if the beam is projected almost parallel to the surface, thereby permitting the creation of shadows to enhance the three dimensional effect. The 'orange peel' appearance of the front surface of the crystalline lens is due to the presence just underneath the anterior capsule of the lens, of the cell bodies of the lens fibres. Optical section of the crystalline lens shows up variations of refractive index and transparency, permitting observation of the Y sutures and retrolental hyaloid remnants. Opacities of the crystalline lens scatter and reflect more light and therefore, show up as white areas against a grey background. Occasionally, due to pigmentation, blue or brown areas may be seen, and in the elderly, the rear layers of the lens appear yellow, proceeding to amber and brown in extreme old age (brunescent cataract). The nucleus of the lens appears similarly yellowed in nuclear sclerosis. Observation of all but the anterior vitreous is usually only possible through a dilated pupil. With increasing age, the anterior vitreous takes on a fibrous appearance.

Returning to the front of the eye, the bulbar conjunctiva, sclera and canthi can be observed by direct illumination using a wide beam. With 40x magnification, it may be possible to see red blood cell groups moving along in the conjunctival vessels. It helps to change the angle of the beam frequently, otherwise specular reflection may mask underlying appearances. By partially everting eyelids, their margins may be examined for abnormalities such as small cysts which might otherwise go unnoticed. The patency of the Meibomian gland ducts can be established by finger manipulation and the puncta viewed. Any aberrant eyelashes can also be detected. These are a frequent cause of discomfort to many patients, especially the elderly. Complete eversion of the eyelids enables any concretions, follicles or papillae to be seen and is an essential for contact lens wearers.

**Tear Film**

Besides the tear film break-up time (TBUT & MBUT) already discussed, a number of other observations on the state of the tears film may be made using the biomicroscope.

If the superficial oily layer of the tears film produces interference colours which colour the reflection when viewing the first Purkinje image of the slit lamp beam, too thick an oily layer is indicated.

Similar interference colours may be seen emanating like waves from the upper eyelid margin at the commencement of a blink. They close together as the upper lid descends and open out as it goes up again. This indicates tears which are very viscous - an aspect which may be affected by diet or drugs. Excessive viscosity may be noted by observing the corneal surface just after the eyelid margins have parted following a blink when an oily looking deposit or 'scum' is left behind. No such deposit remains when tears are of normal viscosity. Even with normal tears, a deposit may be seen on the front of a contact lens, shortly after a blink, but the blink should clear it. If it does not, the tears are too viscous. When the tears are extremely viscous, their flow in the lower rivus towards the punctum is very slow. If the flow is very fast, the tears are too watery. Normal flow is seen when particles or bubbles on the surface move more slowly than those beneath, due to surface tension effects. Another sign is the sheen due to the surface oily layer being compressed at commencement of each blink. It can be seen with a slit beam about 4mm wide and set at 15° to 20° to the microscope axis. When measuring tears film break-up-time, dry spots normally start to appear some 10 to 20 seconds following a blink. If a lash or bubble indents the epithelium, it is normal for the furrow so formed to enlarge gradually for about 5 minutes. Such a furrow will fill with fluorescein and have an oily border. It will then gradually reduce in size until the normal tears film is reformed.

**Use in Contact Lens Work**

Much can be learned about the fit and state of contact lenses by examining them in situ on the eye:
Look at the cornea beneath the lens and this can be done with the lens on the eye. Nicks, cracks and deposits of any kind. Lens surfaces and edges for scratches, during fitting, also look at the fit, position and mobility of the lens as movement with blinking and eye movement. Any bubbles, regions of edge stand-off and blood vessel indentation at the limbus should be easily seen. Overall size of a lens and its measurement may easily be checked when on the eye, either by using a graticule eyepiece or holding a scale close to the eye, when with low magnification, the scale and lens can be seen in focus together. Markings on toric lenses can be assessed for their angle without a graticule by using a magnification of 6x to 10x. Note lens position before, during and after blinking and check that tears flow behind the lens by watching the passage of fluorescein or any tiny bubbles.

II) Soft Lenses - Using white light and wide slit or round patch with direct or diffuse illumination, note lens position with the eyes directed ahead, and lens movement with blinking and eye movement. Any bubbles, regions of edge stand-off and blood vessel indentation at the limbus should be easily seen. Overall size of a lens and its measurement may easily be checked when on the eye, either by using a graticule eyepiece or holding a scale close to the eye, when with low magnification, the scale and lens can be seen in focus together. Markings on toric lenses can be assessed for their angle without a graticule by using an optical section. This can be turned horizontally for 180° markings.

**During Aftercare**

1) **Hard Lenses** - Use fluorescein and check the fit using a circular aperture, blue filter and direct focal illumination. Use a magnification of 6x to 10x. Note lens position before, during and after blinking and check that tears flow behind the lens by watching the passage of fluorescein or any tiny bubbles.

2) **Soft Lenses** - Note their position, centration and mobility as well as the state of the surfaces and edges. Look for limbal injection and blanching of any blood vessels, and check the lens engraving, if present.

After lens removal, study the cornea in more detail and evert the lids.

Around it and attempt to relate any corneal staining or dimples seen to edges, transitions or bubbles, noting for example whether an arcuate stain corresponds to the upper edge position of a lens during a blink when the upper lid pressure may press the edge into the epithelium. Following lens removal, study the cornea in more detail and evert the lids.

**Examination of Contact Lenses**

A measurement graticule is usefully placed in one eyepiece as it allows accurate assessment of eye and lens. The measurement of the horizontal visible iris diameter (HVID) for soft lens fitting and the vertical palpebral aperture for hard lens fitting are examples; also the exact orientation of toric lenses and bifocal segments in specialist contact lens fitting are easily achievable.

By using a suitable holder, the lens surface and edges can be studied with the microscope; or with beam and microscope at 180° to each other, the lens can be placed between them so that the illuminated lens is imaged by the microscope on to a convenient screen such as a white wall (the microscope in reverse acting as a projection system).

**Slit Lamp Examination beyond the Anterior Vitreous**

With the use of hand-held accessories, the slit lamp can facilitate examination techniques to view ocular structures normally beyond the range of routine biomicroscopy. These include stereoscopic examination of the posterior vitreous, ocular fundus, and the angle of the anterior chamber. The ocular tissues and structures normally viewed with slit lamps without adaptation are confined being anterior to the anterior vitreous. This is a limitation primarily due to the refractive power of the cornea and the lens.

Methods currently available to overcome this include:

1. The use of a high powered negative lens (Hruby) to convert the biomicroscope into a telescope thus providing a virtual erect image of the fundus (see figures 12a & 12b). The lens would normally be powered at about -55 D and designed to neutralise the corneal power. Held centrally and as close to the patients cornea as possible, with the slitlamp illumination and observation systems almost coaxial, an image of the fundus is obtained through a dilated pupil. The field of view tends to be limited (about 1 disc diameter) and distorted at the periphery but nevertheless it is a useful and easy method of evaluating the fundus with the slitlamp.

2. The use of Volk high powered positive lenses ranging from +60D to the double aspheric +90D, to convert the biomicroscope into an indirect ophthalmoscope to view a real inverted image of the fundus (see figures 13a & 13b). Held with the steeper curve away from the eye, between the microscope and the eye (not as close to the eye as a Hruby lens), and with the slitlamp illumination and observation systems almost coaxial, an image of the fundus in front of the condensing lens and the biomicroscope, is easily obtained through the dilated pupil. The field of view is in the region of 6 or more disc diameters and working distances are shorter for the higher powered lenses. Also available with "Snap-On" lid control adapters and yellow filters, the higher power condensing lenses give the better field of view but a lower magnification, and vice-versa.
3. The use of a high powered negative contact lens with a flat anterior surface and some gonioscopy coupling fluid (methyl cellulose (2%) or equivalent) to neutralise the cornea and view a virtual image of the fundus with a slitlamp (see figure 14a). This approach allows a view of the fundus, its far periphery in the dilated eye, and the anterior chamber angle in the anaesthetised and undilated eye, with or without built-in mirrors. The most useful of these devices is the -64D Goldmann three-mirror contact lens (see figure 14b).

4. The use of a high powered positive contact lens (around +120D to +155D) with some gonioscopy coupling fluid (methyl cellulose (2%) or equivalent) to view an inverted image of the fundus. The lenses are designed to give a wide field of view (e.g. Volk Quadraspheric gives 15+ disc diameters) and though useful for pan retinal photocoagulation do not provide the magnification necessary for a detailed fundal exam (see figure 15).

Clinical techniques for slit-lamp examination of the fundus

Probably the two most frequently used methods for slit-lamp examination of the posterior vitreous and the fundus are binocular indirect ophthalmoscopy with a Volk +90 and the use of the triple mirrored Goldmann contact lens.

Diagnostic drugs required and preparation of patient

For both techniques, it is necessary to dilate the pupils with appropriate mydriatics, and if necessary, ensuring that no pupil responses are present due to the bright light from the slit-beam (e.g. Tropicamide 1% and phenylephrine 2.5%). Additionally for use of the Goldmann three mirror contact lens, an appropriate topical anaesthetic (e.g. Benoxinate 0.4%) is required (also enhances the action of the mydriatics), as is some coupling fluid like 2% methyl cellulose or equivalent, to cushion the lens.

The techniques

The image obtained through a Volk lens is vertically inverted and laterally reversed. The lenses are used in a manner similar to that in indirect ophthalmoscopy. Position the lens between index finger and thumb centrally over the eye to be examined, almost touching the lashes, whilst resting other fingers on the patients’ slit-lamp forehead rest with the illumination and observation axes coaxial. Using the joystick, the fundus can easily be brought into focus. With a little practice, it is possible to reduce reflections from the lens surfaces by tilting and angling the Volk lens. By manipulating the illumination and magnification of the slit
lamp, it is possible to view the detail of the structures being examined. The peripheral retina may be viewed through an oblique pupil by asking the patient to fixate in different positions of gaze as with direct ophthalmoscopy.

The image through the largest central portion of the Goldmann lens is about 4 disc diameters wide. The two intermediate mirrors allow views of the mid (equatorial) and the far periphery of the fundus, whilst the smallest mirror is used primarily to examine the pars plana and the extreme retinal periphery (and the anterior chamber angle). When viewing through the mirror, the structure being examined is in the opposite location to the mirror and inverted.

Before placing the contact lens onto the cornea, it is recommended that the anterior eye is examined by routine slit lamp microscopy to establish that the eye is suitable to undergo this procedure.

Holding the lens upside-down between the thumb and two fingers with bubble free coupling fluid within the concave surface, ask the patient to look upwards whilst drawing the lower lid with the middle finger of the other hand. Place the lower edge of the contact lens on to the lower part of the eye (between the limbus and the lower lid) and ask the patient to slowly look down whilst pulling the upper lid away and tilting the lens with the coupling fluid onto the anaesthetised cornea. With the lids released, the patient gazing straight ahead, and the lens rotated into position, the examination may begin. By rotating the larger intermediate mirror (equatorial) in all four quadrants, and then the slightly smaller (far periphery) mirror in all four quadrants, the entire fundus may be systematically examined.

After completion of the examination, it is recommended that the eye is once again evaluated to ensure that any lesions due to the procedure (e.g. corneal epithelial damage) are managed appropriately.

Some tips on examination of the posterior vitreous

The use of the slit lamp in examination of the posterior vitreous should be conducted after localisation of lesions or areas of particular interest by ophthalmoscopy.

Regardless of the method employed, for examination of the posterior vitreous, better results are usually obtained when the illumination and the observation axes are adjusted so that they are as close together as is practical, to enable the stereoscopic view of the illuminated fundus.

The whole point of examining the fundus with the slit-lamp technique is to capitalise on the opportunity to evaluate a wider view of the fundus under focal illumination, stereoscopic viewing conditions, and differing magnifications; thus gleaning information not normally available by direct ophthalmoscopy. The examination of the far periphery for small retinal lesions under magnification becomes possible as does confidence in the location of lesions e.g. pre-, intra- or post-retinal. The whole fundus and particularly the macular area can be evaluated for elevated or depressed lesions along with the impact that these have if any, on the apposing tissue. Differentiation between macular cysts and holes becomes easier as does gauging the extent and limits of the disc margins, neural rim tissue, nerve fibre layer and depth of the cupping of the disc.

Clinical Slit Lamp Gonioscopy

Gonioscopy makes it possible to view the normally inaccessible irido-corneal angle of the eye. Although many devices are available to do this, the most popular slit lamp method is by the use of the versatile Goldmann triple-mirror contact lens to indirectly view the angle.

The patient is prepared, save for instillation of the mydriatics, and the contact lens is inserted in the same way after slit lamp examination of the anterior eye, as described previously for viewing the fundus with the Goldmann three-mirrored contact lens.

Because the anatomy of the irido-corneal angle is such that it is easier to identify anatomical landmarks in the inferior quadrant quickly, it is usual to begin by examining the inferior angle which is normally the widest and most pigmented, first. Then proceed in a systematic clockwise direction to examine the rest of the angle. In patients with irides which are a little convex and which get in the way of a clear view of the angle, it is possible, by asking the patient to shift their gaze slightly towards the mirror, to "look over" the iris into the angle. Appositionally closed angles can be "opened" up temporarily by direct pressure on the cornea via the contact lens. This then enables the examiner to view more of the angle. It should be noted that this is not easy with the larger Goldmann lens which has a scleral flange compared to other corneal gonioscopes (e.g. Zeiss four-mirror lens).

After completion of the examination, it is recommended that the eye is once again evaluated to ensure that any lesions due to the procedure (e.g. corneal epithelial damage) are managed appropriately.

Some tips on clinical slit-lamp gonioscopy

Like other clinical evaluation techniques in optometry, the systematic evaluation of the irido-corneal angle is essential to gain an appreciation of the normal anatomy viewed by gonioscopy. Examine each landmark anatomical structure, beginning at the pupil margin working systematically over the iris noting the blood vessels of the angle, to the ciliary body, the scleral spur, the trabecular meshwork, Schwalbe's line and beyond. Decide on the basis of this where the iris inserts into the angle, the shape of the iris, the degree of lens/iris apposition and hence, the width of the angle.

Several systems for grading have been proposed and the reader is referred to the bibliography for a detailed works on the alternatives current.

Specialist Slit Lamp Attachments

The use of slit lamp attachments, namely for applanation tonometry, pachometry, aesthesiometry, tears film evaluation (Tearscope Plus), video image capturing and still photography are beyond the scope of this monograph.

Interested readers will find further information in the list of references and bibliography.
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