KATT Fitting Instructions October 2011

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Background.

The KATT is a 16.50mm miniscleral whose design is based on measurements made of the corneo-scleral junction. This transitional area can best be described in terms of a tangent, or straight line, in that the measurements proved that from a chord of 10.00mm to 17mm, the surface of the sclera is not a curve, but runs tangential to the surface.

The lens has 4 distinct zones: a spherical or aspheric central Optic Zone (10.00mm), a Peripheral Clearance Zone (T1) that runs parallel to the ocular surface out to a diameter of 12mm, a Limbal Clearance Zone (T2) that allows for clearance of the lens at the limbus, and finally a peripheral curve that meets the sclera at a diameter of 15mm. All lenses are manufactured in Boston XO2 in Clear because the lens is sealed and requires a high Dk material (141). The fitting philosophy is based on matching the sag of the eye at a chord of 15mm to that of the lens with an allowance for apical clearance.

Step 1: Determining the sag of the corneo/scleral area at the 15mm chord.

The Smith Technique.

The Smith technique was first described in the early 1980s as a quick, simple method of determining the anterior chamber depth. It is therefore ideal for determining the sag at a chord of approximately 15mm, as is shown in Figure 1.

The line drawn from the anterior lens capsule out to the sclera determines the chord at which the anterior chamber depth is measured. Note that the two lines drawn from this point up to the corneal surface are at a tangent to the surface of approximately 40 degrees.

So, if a lens is to fit this eye, we need to know the depth of the anterior chamber, and the easiest way to do this is by using the Smith Technique. To perform this simple test, you will need to have a slit lamp that will allow you to turn the slit beam horizontal and also a scale that allows you to read off the length of the slit beam.

Figure 1 showing the anterior chamber depth, the chord at ACD and the tangential nature of the corneo-scleral junction.

Smith Technique procedure.

1. The illumination arm must be set at 60 degrees to the microscope. The microscope should be set at the straight-ahead position (i.e. zero degrees.)
2. Turn the slit beam to horizontal and use a narrow slit on bright illumination.
3. Turn the slit length until it is minimal length.
4. FOCUS ON THE ANTERIOR LENS CAPSULE.
5. Have the patient look straight at the R microscope lens for the Right eye and the Left microscope lens for the left eye. The slit beam should always run from the TEMPORAL side, so it will be on your left hand side for doing the patient's R eye, and your right hand side for doing the patient's L eye.
6. You will see a narrow slit reflected from the anterior lens capsule and an out of focus slit reflected from the cornea.
7. Increase the slit length until the in focus slit from the anterior lens capsule JUST TOUCHES the out of focus slit from the cornea. Use your RE for measuring the patient's R eye, and vice versa for the Left eye.
8. Read the slit length off the scale on the slit lamp illumination housing.
9. Multiply this value by 1.40: i.e. if the slit length is 2.4mm, then the corrected value is 2.4 X 1.4 = 3.36mm which is the Anterior Chamber Depth.

The two figures shown above show how the slit beams start off separated, and then come into touch by increasing the slit length. It should be noted that the slit beam MUST remain in focus at the anterior lens capsule, and out of focus on the cornea.

Limitations of the Smith Technique.

This technique was originally devised using a Zeiss slit-lamp, so the accuracy of the slit length measurement scale on your slit-lamp may not be as accurate as the Zeiss instrument. This can lead to marked errors in the measurement of AC depth.
Also, the accuracy of the technique when fitting mini-scleral lenses is poor in cases of Plateau iris.

2. Topography Technique.

Patrick Caroline and Randy Kojima at Pacific University developed this technique using Medmont corneal topography data from 50 normal and keratoconic patients.

1. Capture a corneal topography map that has the largest possible coverage of the cornea.
2. Select "Details" from the "Analysis" tab on the toolbar.
3. Change the Chord value to 10.00mm.
4. Read off the Sag value on the flat meridian, or alternatively, use the mean value between steep and flat.
5. The sag value then has 2.00mm added to it. For example, if the sag at 10.00mm is 2.214mm, then the total sag value of the eye is 2.214 + 2.00 = 4.214mm.
6. Add 0.4mm to this sag. This allows for the required clearance and settling.
7. Go to the Trial set sheet and find the closest sag value lens in the trial set. This is the initial trial lens.

Other Topographers

The above information should be available on other topographers: please consult with the manufacturer on how to access it.

The KATT Trial Set.

The trial set consists of 14 lenses made from Boston XO, Blue. All of the trial lenses have an aspheric BOZR (7.80 E), where the E stands for "elliptical". The lenses range in sag from 4.00mm to 5.60mm. The lower sags are for early cones, and the higher sag lenses for advanced cones and post-graft patients. The Elliptical BOZR is preferred if a cone is being fitted, and a Spherical BOZR for post-graft cases. Note that the Sag @15mm is the most important number. The T1, T2 and CT (centre thickness) are used to refine the fit.

Katt trial set								
#	Sag @ 15.0 (μm)	BASE	Ecc	T1	T2	BVP	CT	OD
1	4000	8.207e	0.50	50	45	+2.00	0.45	16.5
2	4100	7.810e	0.50	50	45	0.00	0.45	16.5
3	4200	7.460e	0.50	50	45	-2.00	0.30	16.5
4	4300	7.150e	0.50	50	45	-4.00	0.30	16.5
5	4400	6.623e	0.98	50	40	-6.00	0.30	16.5
6	4500	6.296e	0.98	50	40	-8.00	0.30	16.5
7	4600	6.000e	0.98	50	40	-9.00	0.30	16.5
8	4700	5.730e	0.98	50	40	-9.00	0.30	16.5
9	4800	5.890e	0.98	45	40	-9.00	0.30	16.5

10	4900	5.635e	0.98	45	40	-10.00	0.30	16.5
11	5000	5.830e	0.98	45	35	-10.00	0.30	16.5
12	5200	5.810e	0.98	40	35	-10.00	0.30	16.5
13	5400	5.325e	0.98	40	35	-15.00	0.30	16.5
14	5600	4.920e	0.98	40	35	-15.00	0.30	16.5

Nomenclature.

Column 1: shows the sag height of the lens at a chord of 15mm. It is this value that is used to determine the initial trial lens, *and not the BOZR.*

Column 2: shows the BOZR of the trial lens. The "e" indicates that the curve is elliptical or aspheric.

Column 3: indicates the eccentricity value of the BOZR.
Column 4: represents the ***Peripheral Clearance Zone (T1)***, which is the area for a chord of 10.00mm to a chord of 12.00mm. The value indicated is the conical angle of that zone. Each 5 degree steepening or flattening, is equivalent to approximately 150um increase or decrease in sag.

Column 5: is the ***Limbal Clearance Zone (T2)*** and is used to alter the clearance over the limbal area. Once again, the indicated value is the conical angle which can be steepened or flattened to increase or decrease the sag. Note that this is more commonly used in the steeper and higher sag lenses.

It is rare to change the T1 in cases of keratoconus. Changes to T1 are more common in post-graft cases.
The lens power is shown in the next column. The lens centre thickness is also shown, and this is used to determine the amount of apical clearance of the lens after insertion.

Trial Lens Fitting.

1. Determine AC depth using the Smith technique and multiply the value by 1.40, or alternatively, use the sag data from topography as outlined above.
2. Go to the trial lens set and find the NEXT HIGHEST SAG from the sag table that comes with the trial set.
3. Apply one drop of anaesthetic to the eye.
4. Clean and rinse the trial lens and fill the lens with SALINE, Ocupure Saline or THERA-TEARS GEL. DO NOT USE ANY OTHER FORM OF PRESERVED SALINE EXCEPT OCUPURE. DO NOT USE ANY FORM OF PRESERVED SOAKING SOLUTION.

5. Wet a fluorescein strip with saline and add a generous amount of stain to the well of saline in the lens. THIS IS VITAL…you will need to be able to see the fluorescein pattern to assess the fit properly.
6. Insert the lens.
7. Place the patient in front of the slit lamp, turn on the blue light and make sure you use a Wrattan Yellow filter to look at the fluorescein pattern.
8. Using the widest beam, assess the fit for the following.
9. There should be an even glow of fluorescein over the entire corneal surface and out onto the sclera. There should be total limbal clearance. If apical touch is present, the lens is too FLAT and must be replaced with the next highest sag trial lens.
10. If the gross NaFl pattern looks acceptable, narrow the slit right down and go to white light and high magnification.
11. Examine the central area first by leaving the illumination at zero and rotating the microscope to the temporal side at a wide enough angle so that you get a good cross-section of the lens and cornea.

12. The central thickness of the trial lens is written on the scale in the trial lens set. The ideal apical clearance ***on insertion*** should be approximately 0.30mm, so you must compare the thickness of the lens to the thickness of the tear layer, which should appear a bright green colour.
13. If the Tear Layer Thickness (TLT) is LESS than 0.30mm, fit the next highest sag lens in the trial set. If the TLT is much greater than the CT of the lens, fit the next lower sag lens in the trial set.
14. Now have the patient look nasally and temporally and examine the TLT at the Limbus. There should be at least 0.20mm of clearance at the limbus.

Figure 4. The apical clearance is shown. Note the central thickness of the trial lens (0.30mm) and the thickness of the bright green tear layer. This is much easier to see on high magnification. Note how the TLT is equal to the CT of the lens. This is the ideal initial clearance.

Figure 5. The clearance at the R temporal limbus is shown. Note that the clearance is still almost the same as the lens thickness, so this is a very good fit.

The lens must be inserted so that there are NO BUBBLES present.

The KATT is a SEALED lens. There will be NO tear exchange, as is the case with all sealed scleral and miniscleral designs.

TRIAL FITTING continued:

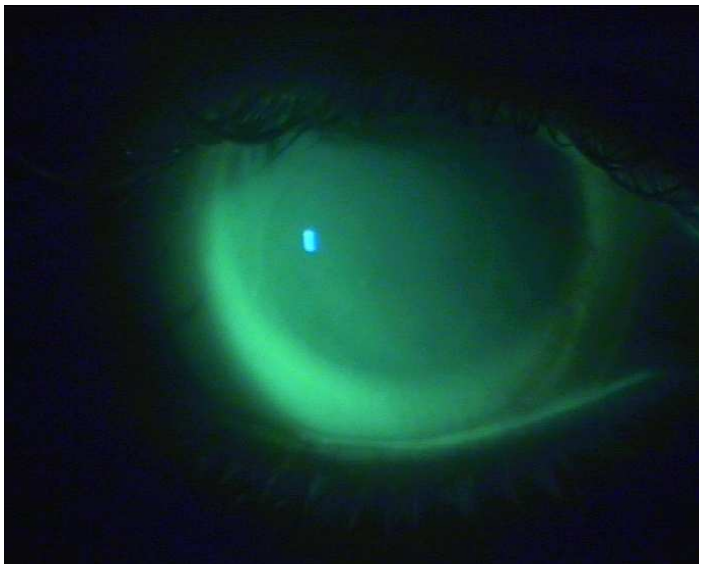

Figure 6. Fluorescein pattern of a lens on a keratoconic eye showing excellent overall clearance from the centre to out past the limbus.

15. The lens must now “settle” for at least 60 minutes, so the patient can be sent out to the waiting room. Do not over-refract at this stage, especially if you have used gel to fill the back of the lens, as this will cause some blurring until it settles.
16. The 60 minute “settling” period is vital: it allows the lens to settle back onto the sclera so that the “true” apical clearance can be determined, and it also allows time for the local anaesthetic to wear off so that the patient gets a real feel for the comfort of the lens.
17. After the 60 minutes (or longer if desired) settling period is over, have the patient return to the examining room and perform the over-refraction before shining more bright lights into their eyes. They may still say that everything is “not quite clear” but this is normal if gel is used. If saline is used, the vision may still be a bit indistinct due to the wetting of the lens. This problem will resolve itself when the patient has worn their own lenses for a few days.
18. Repeat slit lamp examination of gross NaFl with blue light and the Wrattan yellow filter. The fluorescein will still be present as there is very little or no tear exchange.
19. Now look at the apical and limbal clearance with a narrow slit, high illumination and magnification under white light.
20. If the clearance is basically unaltered, you do not need to change anything: simply order the lens with the over-refraction included.
21. If the lens has “settled back” and the apical clearance and limbal clearance have been noticeably reduced, the lens design must be altered to return the lens to 0.30mm of apical clearance and 0.20mm of limbal clearance.

Lens Design Alterations.

If the correct trial lens technique has been followed, you will need to only do two things after the settling period: raise or lower the lens, or in other words, increase the sag of the lens if it is too flat or has insufficient apical clearance, or decrease the sag if the apical clearance was too high.

IF THE APICAL CLEARANCE IS INADEQUATE BUT THE LIMBAL CLEARANCE IS IDEAL.

In this case the simple solution to the problem is to steepen the BOZR and keep all other lens parameters the same.

RULE #1 For each 1.00D change in BOZR, the TLT changes by 0.05mm

Example 1. Assume you have an 8.00 BOZR trial lens and that at the end of the settling period, the apical clearance is 0.40mm. In order to decrease the apical clearance, the BOZR should be flattened by 2.00D to 8.40mm. This will decrease the apical clearance to 0.30mm. The power of the lens should be altered accordingly. If the BOZR is flattened by 2.00D, the lens MUST have an extra 2.00D of PLUS power added to it.

Example 2. If the same 8.00 BOZR lens settles back and only shows 0.20mm of apical clearance, but the limbal clearance is ideal, then the apical clearance needs to be increased by 0.10mm or the BOZR steepened by 2.00D to 7.60mm.

If the apical clearance and limbal clearance are inadequate after settling.

In this case the whole sag of the lens must be increased. However, the next steepest lens in the set may be too steep, so how do you alter the lens “half way”?
As stated in the introduction, the KATT has a second tangent that can be used to “raise and lower” the lens fit without changing the BOZR. This is called the Limbal Clearance Zone (T2) and its value can be altered to achieve the correct limbal clearance.

The standard T2 is nominated as per the trial set table. If the sag of the lens needs to be increased, T2 sag can be altered in variable “steps”. Each 1 degree step changes the height of T2 by 30 microns. Changes to T2 are done simply by changing the angle. For example, if T2 is 45, to increase the limbal clearance by approximately 150um the angle needs to be steepened by 5 degrees to 40.

RULE #2. Each change of 5 steps changes the sag by approximately 0.150mm.

EXAMPLE.

The trial lens is 7.15e/50/45 sag 4.300. Assuming that this lens has 0.20mm apical clearance, and the same at the limbus, the sag will need to be increased. If the T2 value is steepened from 45 to 40, the sag of the lens will be increased by 0.150um, giving a limbal clearance of approximately 0.35mm.
If the apical clearance is too great, say 0.45mm and the limbal clearance also excessive, but the next flattest trial lens is too flat, then flattening T2 by 5 will achieve the desired drop in sag of 0.150mm.

Important note.

The most common problem associated with fitting is that the lens settles back too much after 1-week. It is vital that the trial lens be worn for 30-60 minutes prior to doing a final evaluation. If the initial assessment shows 0.30mm of clearance, which ***then reduces to zero or apical touch after 30 minutes, the next steepest lens MUST be trialled and allowed to settle. It is always wiser to err on the side of too much apical clearance than not enough.***

Instructions for Practitioner Insertion and Removal of Trial Lens.

1. Remove the trial lens from the container and rinse the Boston Conditioning solution off the lens with either Re-Nu, Opti-Free, Aquify or other soft lens solution.
2. Attach a green dual barrel suction cup to the front surface of the lens so that the suction cup is in the inferior half of the lens.
3. Fill the back surface of the lens to the top with either non-preserved saline or Ocupure Saline.
4. Add fluorescein by wetting a fluorescein strip with saline and dipping it into the saline in the back of the lens.
5. Add one drop of local anaesthetic to the eye(s) to be fitted.
6. Advise the patient to keep BOTH eyes wide open and look straight ahead and slightly down.
7. Retract the upper lid with the thumb or forefinger of your left hand. Pull the lower eyelid out of the way with the fourth finger of your right hand whilst holding the suction cup and lens with the thumb and forefinger of the right hand.
8. QUICKLY apply the lens to the eye and SQUEEZE the barrel of the suction cup. This will gently force the lens onto the eye. Do not allow any air bubbles to get into the post-lens tear film.

Removal.

Removal of the lens requires the use of a blue DMV 45 degree contact suction cup as per the following.

1. Have the patient look upwards.
2. Retract the lower lid so that it is just below the inferior edge of the lens.
3. Push gently but firmly into the sclera through the lid margin so that the suction at the edge of the lens is broken ***and a large air bubble is introduced into the post-lens tear layer.***
4. With some wetting solution applied to the suction cup, place it onto the inferior ¼ of the lens and lift the lens off the eye. If there is too much resistance, repeat step 3 above.
5. It is normal for the eye to feel slightly dry following lens removal. This should only last for 5 minutes. Lubricants can help. It is also normal to see some reflex conjunctival injection for a few minutes, with the presence of an edge compression ring on the conjunctive similar to a tight soft lens. This will also resolve in a few minutes.

Excessively tight edge.

In very rare cases, the edge compression ring is obvious with the lens in. If this occurs, consult the lab so that a different edge design can be made.

Insertion technique for patients.

1. Place the lens on the suction cup, slight off centre, and hold between thumb and forefinger. (Use the green dual barrel suction cup).
2. Fill the lens with saline.
3. Lean over until the face is parallel to the table surface.
4. Retract the upper lid with the left index finger (for R eye).
5. Pull the lower lid down with the fourth finger of the R hand.
6. Place the lens on the eye and squeeze the suction cup.

Patient removal of the lens.

The removal technique is the same as that shown above for practitioners. It must be stressed to patients that the seal must be broken before the lens can be removed.
The suction cups must be wiped clean and left dry at all times when not in use.

Cleaning and disinfection is carried out in the usual manner with Boston Cleaner and Conditioner.

Adaptation and wearing time.

Patients are advised to start wear at 6 hours on the first day and increase wearing time by 2 hours per day. All waking hours wear is possible in most cases. Post-graft cases with less than optimum endothelial counts are advised to limit wearing time to from one hour post waking in the morning, and removal at 1 hour prior to retiring at night or whenever any haziness of vision occurs.

It normally takes patients about 1 week to become really proficient at insertion and removal, and they may complain of some haziness of vision. This is due to mucus build-up in the post lens tear layer, and it is not uncommon that they will need to remove and re-wet the lens with saline once or twice a day for the first few weeks. Once the eye totally adapts to the lens, it is rare that the lenses need to be removed for cleaning or re-wetting during the day.

If lenses are removed for cleaning, Boston Cleaner CANNOT be used as the lens will not re-wet. In these cases, the old-style daily detergent cleaners work the best, followed by re-wetting with Boston Conditioner and a saline rinse.

The lenses will need to be polished annually. Menicon Progent is recommended for routine maintenance on a monthly basis. The lens clasps in the Progent Kit can be prised apart wide enough for the lens to fit.

KATT lenses have some major advantages over other lens designs for Keratoconus and post-graft fitting:

1. They are very comfortable to wear.
2. They cannot fall out or be washed down the sink.
3. It is virtually impossible to get dust under them, making them ideal for those who work in dusty and dirty environments.
4. Because they are fitted with adequate apical clearance, the useful life of the lens is extended well past the usual 1-2 years seen in keratoconus fitting.
5. Patients can go swimming in the lenses without fear of loss. However, they MUST remove, rinse and clean the lenses thoroughly after swimming.
6. The lenses are intended for DAILY WEAR ONLY.

For ongoing support and advice, please contact Capricornia Contact Lenses (Don Noack) or John Mountford.

Consumer Guide

Proper Application and Removal of Scleral Lenses

View Online Video
www.scleralcontactlens.com

This brochure was designed to assist you in the proper application and removal of your scleral contact lenses.

Follow Your Practitioner's Instructions

It is important to follow your eye care practitioner's instructions for the proper use of your scleral contact lenses, including the proper use of the lens care products you were prescribed.

Should you experience redness of the eye, eye discomfort or irritation, changes in your vision and/or excessive tearing while wearing your scleral lenses, remove your lenses immediately and contact your eye care practitioner.

The application and removal of your scleral contact lenses can seem intimidating at first. But if you follow these instructions, the process can be quite simple.

Proper Hygiene

Proper hygiene is the first step in successful lens care. Wash your hands with a mild soap and dry your hands with a lint free towel prior to handling your scleral contact lenses.

Lens Handling

Getting in the habit of working with the same lens first will help you to avoid mixing up your lenses prior to applying them.

For example, if you're right handed, you may want to start the lens application process with the right lens each time.

Starting with the right lens, carefully remove your scleral lens from the storage case.

Ensure that your lens is clean, clear of lint or debris and that your lens does not have any chips or cracks.

Rinse the lens with fresh preservative-free saline solution to remove any residual storage solution that may have preservatives in them.

Applying Your Scleral Lens

Place your scleral lens on two or three fingers by forming a "tripod" with your thumb, index and middle finger. This will make it easy to keep the lens balanced.

Fill the entire bowl of the lens with preservative free saline. Position your head parallel with the countertop or table and look straight down.

To apply your scleral lens, you will need to separate your eyelids in order to position the lens on the eye. This can be accomplished by using your free hand to pull the upper lid up and the ring finger of the hand with the lens on it to pull away the bottom lid.

Slowly move the lens toward the eye. Gently apply the lens directly on the eye and over your pupil. Release the lids and blink several times to clear the excess fluid. The lens will automatically center.

Inspecting Your Scleral Lens

Inspect the lens on the eye to make sure there are no air bubbles trapped under the lens.

If you notice an air bubble trapped underneath the lens, you will need to remove the lens and reapply it.

Applying Your Scleral Lens Using A DMV® Scleral Cup™

You may use a special device, called a DMV® Scleral Cup™ to support the lens for application, if desired.

The application process with the DMV Scleral Cup starts by lightly squeezing the tapered handle so you create a mild suction.

Carefully place the scleral lens on the top of the DMV, making sure it is centered. When the lens is centered on the DMV, stop squeezing the device.

This will create a mild suction and your scleral lens should be securely positioned on the DMV Scleral Cup. Completely fill the bowl of the scleral lens with a preservative free saline.

Position your head parallel with the countertop or table and look straight down.

To apply your scleral lens, you will need to separate your eyelids in order to position the lens on the eye.

This can be accomplished by using the index finger of your free hand to pull up your upper lid, while using your middle finger to pull your bottom lid down.

Slowly move the lens toward the eye. Gently apply the lens directly on the eye and over your pupil.

Once the lens is on the eye, a light squeeze of the tapered handle will release the lens from the DMV Scleral Cup. Release the lids and blink several times to clear the excess fluid.

The lens will automatically center.

Wash the DMV Scleral Cup frequently in warm soapy water and let air dry.

Removing Your Scleral Lens

Make sure you have a clean lens storage case, a clean towel and your prescribed lens care solution.

Helpful Tips:

Looking at the mirror, take the index finger and press with the lower lid into the white of the eye, just below the lens.

When the suction is broken, a bubble will be present under the lens.

This lens is now ready to be removed with the DMV 45.

Removing Your Scleral Lens With The DMV© 45™

The DMV 45 has a 45-degree angle which keeps the fingers out of the line of sight while removing the scleral lens.

Looking in the mirror, pull your lower lid away from your cornea to expose the lower edge of the lens.

Hold the handle of the DMV 45 and carefully place the device on the lower edge of the scleral lens.

Once the DMV 45 is adhered to the scleral lens, gently pull the lens away from the eye.

With the lens resting on the DMV 45, gently move the lens off the device using your thumb and index finger.

Follow your practitioner's lens cleaning instructions once the lens is removed. Place your lens in the correct side of the contact lens case and repeat the removal instructions for your other eye. Wash the DMV 45 frequently in warm soapy water and let air dry.

Proper Lens Care for Your Scleral Lenses

Your eye care practitioner will review the proper lens care solution for cleaning, rinsing and disinfecting your scleral contact lenses.

Refer to the lens care package insert, or call your eye care practitioner with questions regarding the proper care of your scleral lenses.

What Should I Do If I Lose or Break My Scleral Lens?

Having a backup scleral lens will eliminate any unforeseen circumstances by losing or breaking a lens. More importantly, your vision will be uninterrupted.

Talk to your eye care practitioner about the importance of having a backup or spare set of scleral lenses.

A new method of estimating the depth of the anterior chamber.

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A new method of estimating the depth of the anterior chamber

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SUMMARY A new method of estimating the depth of the anterior chamber with an accuracy of approximately 0·1 mm is described. The estimate is made with a conventional Haag-Streit 900 slit lamp without any extra attachments.

Measurement of the depth of the anterior chamber can be carried out under clinical conditions by means of the attachment to the Haag-Streit 900 slit lamp, which is based on the method of Jaeger (1952). Photographic measurements can be made as described by Heim (1941), Bleeker (1960, 1961), and Brown (1973), and ultrasonic techniques can also be used.

An ingenious optical device embodying 2 pairs of apertures, each providing independently focusing double pencils—1 pair to be coincident on the corneal endothelium and 1 on the lens capsule—was described by Stenstrom (1953) as a modification of a device invented by Lindstedt (1916). All these methods, however, require the use of special attachments to the slit lamp, with or without photographic techniques in addition.

The method to be described uses the standard model Haag-Streit 900 slit lamp alone; no extra apparatus is required.

Technique

The slit-beam rotating device is pushed fully to the right so that the slit is horizontal. The angle between the slit beam and the microscope is set at 60° and locked (Fig. 1). For measurement on the right eye the apparatus is arranged so that the slit beam is on the operator's left (the patient's right) and *vice versa* for the other eye. The right eyepiece is used for the right eye and the left for the left eye.

The microscope is aimed so that it is pointing straight ahead, that is, in the optical axis of the patient, and the patient is asked to look straight ahead. The apparatus is moved forward by means of the joystick until the slit beam is focused on the cornea.

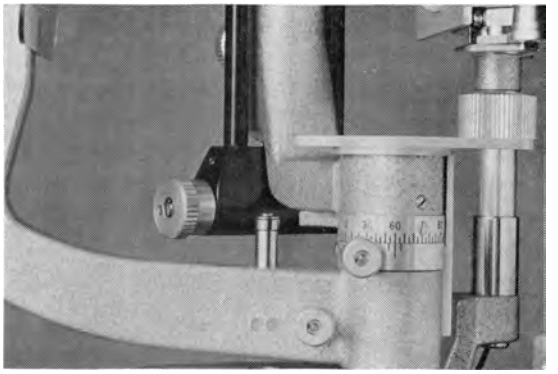

Fig. 1 *Angle between slit lamp and microscope set at 60°*

The thickness of the slit is not vitally important. Preferably a fairly solid beam is used, not a wafer-thin slit, and the technique is slightly easier if the tear film is lightly stained with fluorescein as in applanation tonometry. The length of the slit used can be read on the scale situated on the upper part of the lamp housing (Fig. 2).

The right-hand edge of the slit beam is carefully observed, and the slit beam is altered in length by the knurled knob provided. When the slit is long the picture obtained is as follows: To the left is the sharply focused slit image on the cornea. As one looks along this to the right, the image suddenly becomes more blurred; the blurred zone is the out-of-focus slit image on the anterior lens capsule and, depending on the size of the pupil, more to the right on the iris.

If the slit is considerably shortened, the picture viewed from left to right is as follows: The left end of the slit image is light green owing to the tear film.

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Immediately to the right of this and continuous with the green band the strip is white as it traverses the corneal stroma. Next there is an optically empty gap until the out-of-focus slit image on the lens and iris is reached (position *A*, Fig. 3). The slit is now lengthened until the gap is just obliterated. At this moment the optical conditions are such that the right-hand edge of the slit image on the cornea (at endothelial level) is coincident with the left-hand edge of the slit image at the anterior lens surface (position *B*, Fig. 4).

A simplified optical diagram of the condition is shown (Fig. 5). The true optical diagram would be much more complicated owing to refractive deviation of the slit beam, but for descriptive purposes at this stage the simplified diagram will suffice.

Considering Fig. 5:

BC_1 B_1 is the path of the left edge of the beam,
AC A_1 is the path of the right edge of the beam,
CC_1 is the slit length.

The anterior chamber depth is the side, CB_1, of the triangle, $C\ C_1\ B_1$, of which 1 side is known (CC_1) and angle CB_1C_1 is also known ($= 60°$).

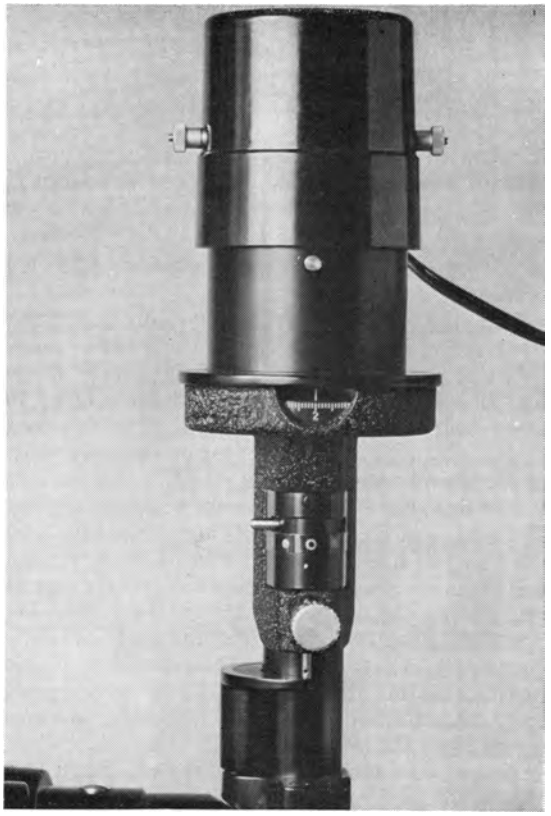

Fig. 2 *Scale for measurement of slit-length*

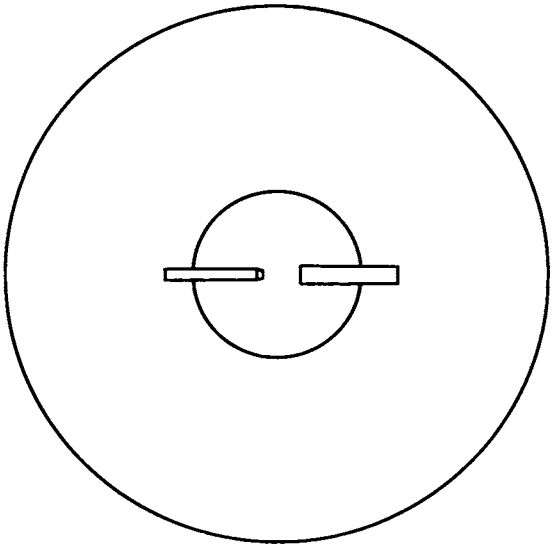

Fig. 3 *Horizontal slit beam in position A*

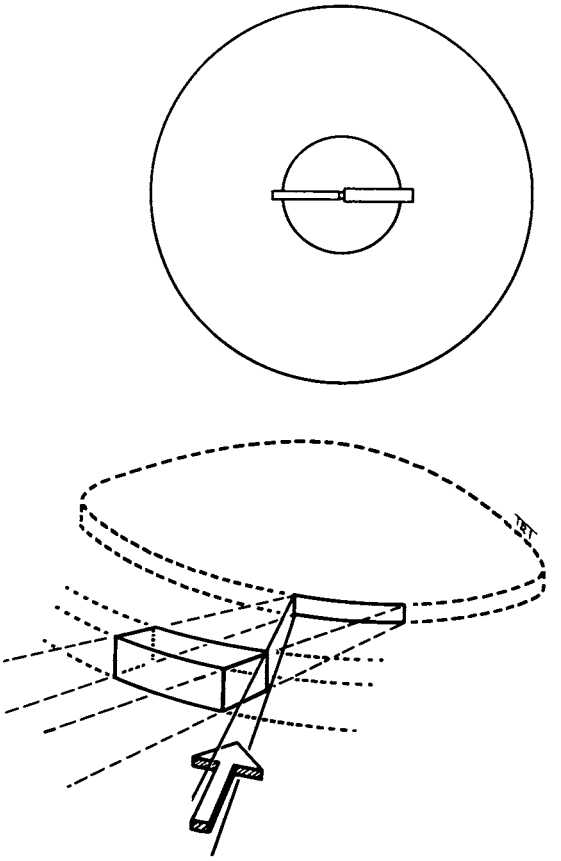

Fig. 4 *Horizontal slit beam in position B*

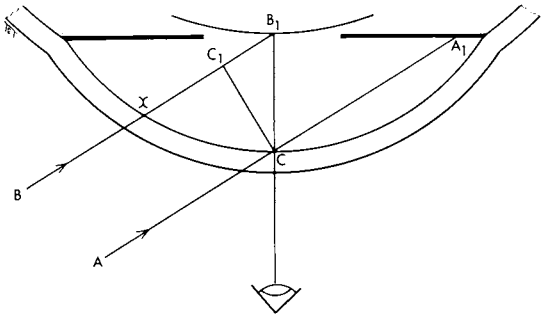

Fig. 5 *Simplified optical diagram of slit beam traversing the anterior chamber*

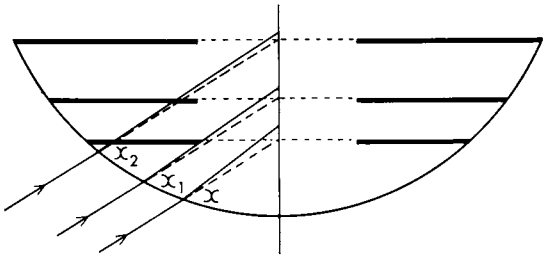

Fig. 6 *The path of the left-hand edge of the slit beam to show deviation at its point of incidence at the cornea. The wider the slit the less the deviation, since the incident angle decreases, as at* x, x_1, x_2 . . .

Therefore the length of CB_1 (the depth of the anterior chamber) is as follows:

$$\text{Sin } 60° = \frac{CC_1}{CB_1} \quad \text{or} \quad CB_1 = \frac{CC_1}{\text{Sin } 60°}$$

Now sin 60° is 0·866. Thus, with a slit length of, say, 2 mm, the anterior chamber depth should be

$$\frac{2}{0{\cdot}866} = 2{\cdot}309.$$

But this would be true only if no refraction of the beam occurred, which is obviously not the case. In fact the deviation of the left-hand edge of the beam is what is of significance in the observation which has to be made (Fig. 6), and this affects both the length of side CC_1 and angle C_1B_1C in Fig. 5.

Furthermore, referring again to Fig. 6: as the slit is lengthened the deviation of its left-hand edge at points x, x_1, x_2, etc., becomes progressively less, further complicating any attempt at an accurate computation of chamber depth.

Fig. 7, which is taken from Jaeger's paper, shows the optical conditions for a ray entering the eye. Ignoring most of the labelling, which is used in Jaeger's text to develop a slightly different theme, we find the ray of interest in our case is ray number 2 (entering at 40° instead of 60°, as in our method). The diagram shows clearly how the ray is deviated towards the normal to the cornea OA, thus changing the position of the anterior lens surface from its true position *C* to an apparent position *B*.

Since the present method did not appear to be suitable for deriving the chamber depth by direct calculation, it was decided to proceed by making a series of observations and comparing the slit length required to attain position *B* (Fig. 4) with an anterior chamber-depth measurement by means of the conventional attachment to the Haag-Streit slit lamp.

The results are shown in Table 1 and Fig. 8. It will be seen that there is a very good correlation between the 2 sets of readings.

The ratio of the means of:

$$\frac{\text{Goldmann readings}}{\text{Slit lengths}} = 1{\cdot}395.$$

If there were to be a simple proportional relationship between the two, then multiplying the slit length by 1·395 (say, 1·4) should give the Goldmann equivalent. Testing this method on a number of occasions subsequently has shown that this is broadly true, but again there appears to be some inconsistency in results which remains to be explained.

Analysis of the figures can be carried out by comparing each Goldmann result with its corresponding 'slit-length' reading to see how consistent the results are. The regression coefficient of Goldmann readings against slit-length readings can be calculated in two ways—either taking the Goldmann readings as the independent variable and the slit-length as the dependent or *vice versa*. In the first instance, having determined the regression

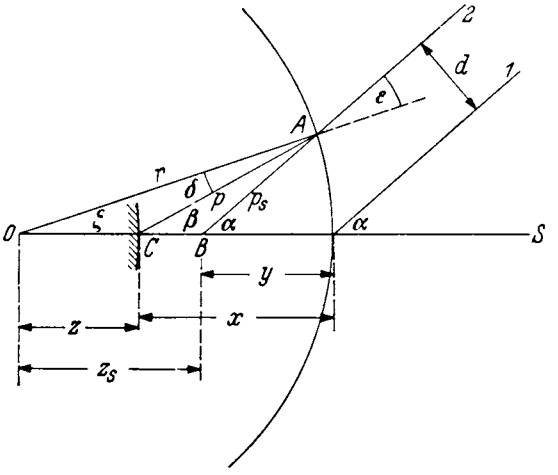

Fig. 7 *Diagram from Jaeger (1952)*

Table 1 *Slit readings. Numbers 3, 13, 21 isolated right eyes; numbers 42, 50, 56 isolated left eyes; in the remainder right and left pairs are present but are not arranged as pairs in the Table*

Eye No.	Slit length (x value)	Actual Goldmann readings (y value)	Calculated Goldmann readings (y predicted)	Error
1	1·5500	2·1000	2·2394	+0·1394
2	1·9500	2·6000	2·6862	+0·0862
3 R	2·4000	3·2000	3·1889	−0·0111
4	1·7000	2·5000	2·4070	−0·0930
5	2·3000	3·0500	3·0772	+0·0272
6	1·5000	2·2000	2·1835	−0·0165
7	1·5500	2·5000	2·2394	−0·2606
8	1·8000	2·4000	2·5187	+0·1197
9	1·6000	2·2000	2·2953	+0·0953
10	1·4000	1·9000	2·0718	+0·1718
11	2·1000	2·9000	2·8538	−0·0462
12	2·1000	2·8000	2·8538	+0·0538
13 R	3·1000	3·7000	3·9709	+0·2709
14	1·6000	2·1000	2·2953	+0·1953
15	2·2500	3·0500	3·0214	−0·0286
16	2·0000	2·8000	2·7421	−0·0579
17	1·6500	2·7500	2·3511	−0·3989
18	2·1000	2·8000	2·8538	+0·0538
19	2·0000	2·7500	2·7421	−0·0079
20	1·1000	1·7000	1·7367	+0·0367
21 R	1·2000	1·7000	1·3484	+0·1484
22	1·7300	2·3300	2·4405	+0·1105
23	1·2500	1·9000	1·9043	+0·0043
24	1·6000	2·3500	2·2953	−0·0547
25	2·2000	3·1500	2·9655	−0·1845
26	1·4000	2·0000	2·0718	+0·0718
27	2·0000	2·9000	2·7421	−0·1579
28	2·0500	2·7000	2·7978	+0·0979
29	1·5500	2·2000	2·2394	+0·0394
30	1·9500	2·7500	2·6862	−0·0638
31	1·8000	2·5500	2·5187	−0·0313
32	2·3000	3·0500	3·0772	+0·0272
33	1·5000	2·2000	2·1835	−0·0165
34	1·7000	2·6000	2·4070	−0·1930
35	1·7500	2·4500	2·4628	+0·0128
36	1·4000	2·1500	2·0718	−0·0792
37	1·3500	1·9500	2·0160	+0·0660
38	2·2000	2·9000	2·9655	+0·0655
39	2·1000	2·8000	2·8538	+0·0538
40	1·6000	2·3000	2·2953	−0·0047
41	2·3000	3·1500	3·0772	−0·0728
42 L	1·6000	2·3000	2·2953	−0·0047
43	2·1000	2·8000	2·8538	+0·0538
44	1·6000	2·2500	2·2953	+0·0453
45	2·1300	2·9000	2·8873	−0·0127
46	2·1000	2·7500	2·8538	+0·1038
47	1·4000	1·9000	2·0718	+0·1718
48	1·7300	2·5000	2·4405	−0·0595
49	1·2500	1·9500	1·9043	−0·0457
50 L	2·6000	3·4800	3·4123	−0·0677
51	1·6000	2·4000	2·2953	−0·1047
52	2·3000	3·1500	3·0772	−0·0728
53	1·9500	2·7000	2·6362	−0·0138
54	2·0000	3·0000	2·7421	−0·2579
55	2·0500	2·7500	2·7979	+0·0479
56 L	1·2000	1·8000	1·8484	+0·0484

Standard deviation of the errors = ±0·1176

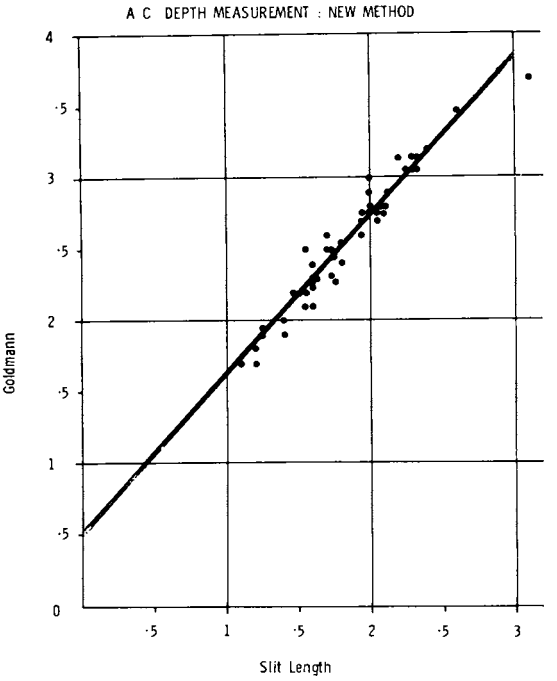

Fig. 8 *Plot of slit length readings against corresponding Goldmann observations (left and right eyes).*

Slope (m) = 1·117. SE = 0·04068. Intercept on *y* axis = 0·5079. Correlation coefficient = 0·96603. *x* mean = 1·82661. *y* mean = 2·54839

coefficient and intercept on the *y* axis, the expected slit-length reading corresponding to the actual Goldmann reading can be calculated, and in each case there is found to be a small error (known as the residual). A preliminary study of this (not illustrated) suggested an error of approximately 0·100.

One is now in a position to look at the regression using the slit-length readings as though they were the independent variables and thus calculating what the Goldmann reading ought to be if the slit reading was in fact 'correct'. (This is rather like having a thermometer marked with a scale in some sort of arbitrary units: after a suitable series of experiments one is able to say that a given reading on the arbitrary scale corresponds to a certain reading on a thermometer accurately marked in degrees Celsius; although in our case the arbitrarily marked thermometer, our slit reading, *and* the so-called accurate thermometer, the Goldmann readings, are probably both subject to some errors.) Clearly, however, the method is of no use if one has to refer each slit reading to the computer centre, so that a simple method of converting slit-length readings to anterior chamber depth is required. This can be done most easily by referring to a graph setting out the re-

gression line of slit length against Goldmann readings or by calculation using this formula:

$y = mx + b$ where m is the slope (regression coefficient) and b is the intercept on the y axis.

Substituting these figures we have:

Calculated Goldmann reading = (1·117 × slit reading + 0·5079).

Using no. 1 in the Table as an example, we find that the slit length found (1·5500) gives a calculated Goldmann reading of 2·2394, whereas the Goldmann reading actually found was 2·100, an error of 0·1394. Similarly, in no. 19, where the slit-length reading is 2·0000, the Goldmann reading can be calculated as 2·7421, whereas the reading actually found was 2·7500, an error of –0·0079.

In short, therefore, it appears that the slit-length method consists in measuring the slit length required for coincidence as described, multiplying the result by 1·117, and adding 0·5079, or, simplifying, G = SL × 1·1 + 0·5, an extremely simple and quick calculation.

The error to be expected in such a method can be approximately determined by calculating the standard deviation of the errors listed in the right-hand column in the Table. This comes out at ±0·1176.

There remains, however, the anomaly that as slit-length and Goldmann readings approach zero they should, theoretically, reach it at the same time. In other words the regression line in Fig. 8 ought to pass through zero, which it does not.

In fact the relationship between slit-length and chamber depth is probably not properly represented by a straight line owing to the influence of the corneal refraction varying at different slit lengths, as shown on Fig. 6. Dr Swinscow (personal communication) feels that it is possible to envisage a shallow curve passing through most of the points which would unite a position near 0 with the outermost dot in the right-hand corner, but that a straight line provides a good approximation within a range that excludes the top right-hand dot.

The final conclusion, therefore, has to be that an exact and simple relationship cannot be demonstrated over the whole range, but for slit lengths of 1 to 2·5 mm the simple ratio quoted earlier (1·4) is sufficiently near the truth to be of clinical utility. In practice this is of great clinical value for the following reasons. Slit lengths of below 1 mm cannot be used because they are not marked on the instrument, and slit lengths in excess of 2·5 mm imply a chamber depth of at least 3·0 mm, as shown on the graph.

In summary, it seems reasonable to claim that the technique provides a quick method of estimating chamber depths between the range of 1·4 and 3·0 mm, a useful range in many clinical conditions.

Discussion

A quick and simple method of measuring anterior chamber depth is especially useful in closed-angle glaucoma, where the diagnosis may depend to some degree on recognition of a shallow chamber and the ability to measure it.

Although mydriatic glaucoma is rare, it is helpful to have a record of the chamber depth before instillation of a mydriatic, particularly, when a clinical estimate by simple observation has given rise to suspicion. A chamber depth of 2 mm or less should be regarded with considerable anxiety, especially if mydriasis is contemplated.

Variations in chamber depth at various times, for example, before and after mydriatics or miotics, are sometimes of interest and may be surprisingly large. Similarly, variations in depth between the 2 eyes may also be found, especially where there are unequal degrees of maturity of cataract. An eye with a mature cataractous lens may show either a much shallower or, alternatively, a much deeper chamber than the fellow eye, since the lens may swell or shrink when cataractous.

Measurement of anterior chamber depth is also valuable before considering implantation of an acrylic lens in the anterior chamber.

A final point may be of some interest: the coincidence method of measuring chamber depth measurement tends to give very similar values for the right and left eye, and it will be noted that the technique is symmetrical, the incident beam being directed in each eye from the temporal side and the axis of observation being approximately along the optic axis. In the Haag-Streit depth-measuring apparatus the incident beam enters along the optical axis, but the observation axis is not symmetrical for the 2 eyes, being from the nasal side in the case of the right eye and the temporal for the left.

I have detected a slight, but definite tendency for the anterior chamber depth estimate on the left eye by the Haag-Streit method to be slightly higher (by 0·023 mm). This has also been reported by Lowe (1968). It seems unlikely that the left chamber is in fact deeper than the right, and the coincidence method described does not indicate that this is so, since by this method the difference is 0·003. Hence it may be that this new method of measuring chamber depth is in fact slightly more accurate than the Goldmann system in some respects, not of course in providing an actual measurement of depth, which

it is unable to do, but in so far as it can confirm that 2 chambers are of exactly equal depth.

My thanks are due to the Statistical Department at the Institute of Ophthalmology, and to Dr T. D. V. Swinscow for valuable advice and to Miss J. Quaife for secretarial assistance.

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This little scleral lens is easier to fit and less expensive than its big brother

A new miniscleral design

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The lens of 'last resort' for extreme cases of keratoconus, post-graft and general corneal distortion has always been the scleral lens, which has undergone a renaissance since the introduction of GP materials, but they are expensive and very difficult to fit. Over the past few years, a new form of scleral lens, the miniscleral, has become very popular here and overseas in preference to the older full scleral. This is due to relative ease of fitting and lower expense.

Miniscleral lenses also have their problems, due to the basic multicurve design used by most manufacturers. These include compression of the limbal stem cell zone and marked rebound conjunctival hyperaemia following removal (Figure 1).

This is due to the relatively high suction effect of the lens and the way in which the peripheral curves meet the sclera. The ability to design a lens that has the correct fitting relationship to both the limbal area and the scleral contact zone has always been limited by the lack of knowledge about the actual shape of theses areas of the anterior eye.

In October 2008, Patrick Caroline came over for the Ortho-K conference and showed me the most amazing slide I had ever seen. He had been using the Visante OCT (Carl Zeiss) to try and get an idea of the actual shape of the limbal/scleral zone and design a lens that would achieve the correct fitting relationship.

Figure 2 shows a Visante cross-section of the cornea and sclera. Pat Caroline had noticed that from a chord of 10.00 mm across the cornea out to about 15 mm, the shape of the sclera was a tangent: in other words, this particular area of the limbus and sclera is not a curve of approximately 14 mm radius as previously thought, but more like a straight line.

We decided to join forces and get as much data as we could on as many eyes as possible so we could set about designing a new miniscleral that would totally clear the limbal stem cell zone and meet the sclera in such a way as to minimise compression and lower the suction effect. With the gracious help of Carl Zeiss Australia (thanks to David Raven), a Visante was installed in the practice and Luke Arundel and I started measuring eyes.

If the corneo-scleral junction zone is a tangent, what are the mean angle and the standard deviation? What chord is it measured over? What is the sag of the cornea over this chord? These are some of the questions that needed to be answered.

It does not matter how good all the data are if an OCT is needed to get it. What we needed was a quick, simple and accurate method of measuring anterior chamber depth. The Smith technique is such a method. Any slitlamp that has the ability to rotate the slit horizontally and a measuring scale to

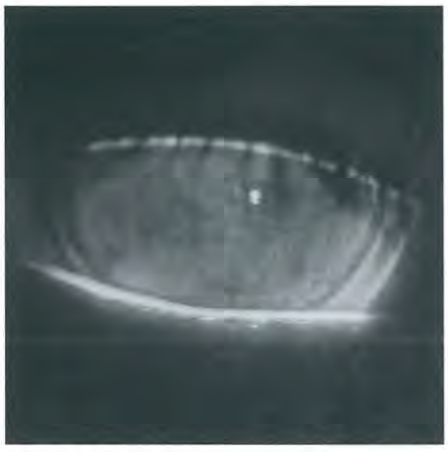

Figure 1. Marked corneal staining due to peripheral curve compression in a patient wearing a multiband miniscleral

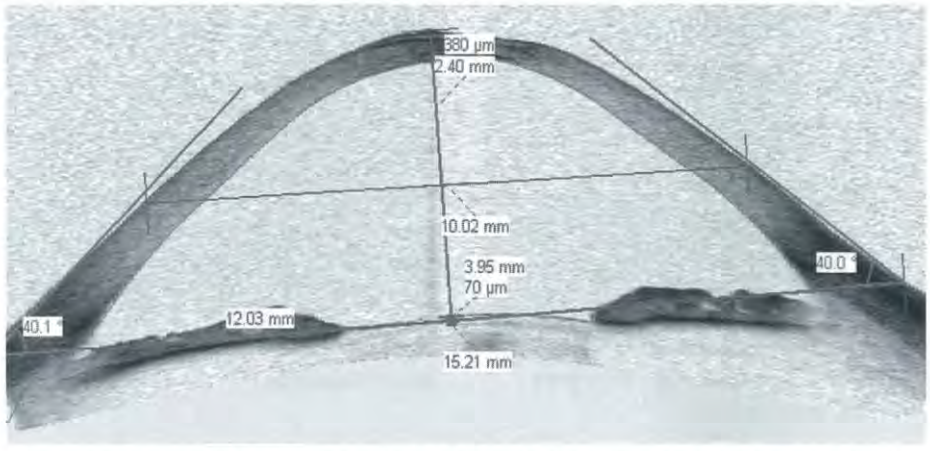

Figure 2. A Visante OCT cross-section of the anterior eye. Note that the peripheral cornea and sclera can be represented by a straight line or tangent.

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A new mini-scleral design

measure the length of the slit will work. For a full description of the technique, go to the Zeiss website and look for the Anterior Chamber pdf.

The chord was measured at the anterior lens capsule out to the sclera, and the tangents measured from this point to the 10.00 mm chord on the cornea. The results gave a mean chord of 14.91 mm and a mean anterior chamber depth of 3.33 ± 0.47 mm when measured with the OCT. By comparison, the mean corrected ACD with the Smith technique was 3.33 ± 0.49 mm. The mean cone angle was 50.5 ± 2.1 degrees.

Don Noack and I then designed a 16.5 mm diameter lens with a central spherical or aspheric zone of 10.00 mm, a tangent that runs parallel to the corneal surface, a second tangent that is used to raise or lower the sag of the lens, and a unique edge design to meet the sclera. By analysing the range of sag heights, we were able to produce a trial set with 10 lenses with a sag difference of 150 µm between lenses, and two 'outsider' lenses for those really ectatic grafts.

Fitting philosophy

This is very simple and straightforward. All the practitioner needs to do is measure the ACD with the Smith technique, make the correction by multiplying the slit length by 1.40, and then find the closest matching trial lens that has a sag slightly greater than the Smith value. The BOZR does not matter.

The lens is inserted and allowed to settle for 30 minutes. The first thing to look at is the fluorescein pattern. This should show an even glow of fluorescein out past the limbus (Figure 3). A narrow slit is then used to determine the clearance at the limbus. Using the temporal limbus, have the patient look nasally until the slit beam is normal to the limbus. Swing the microscope arm to as large an angle as possible, and determine the depth of the tear layer (a bright green) to the thickness of the lens. If the clearance is similar to the thickness of the lens, the peripheral clearance is ideal (Figure 4). If the clearance is excessive, flattening the second tangent lowers the sag of the lens to the required level. Alternatively, if the clearance is insufficient, steepening the second tangent will raise the clearance.

The apical clearance is then determined by using a narrow slit and high magnification. The central thickness of the trial lens is written on the lens container, so all the practitioner needs to do is compare the apical clearance to the thickness of the lens. If the clearance is equal to the CT of the lens, the fit is ideal (Figure 5).

If the clearance is less than the CT of the lens, the BOZR is steepened to bring the apical clearance up to a value equal to that of the CT. The reverse occurs if the clearance is too great: the BOZR is flattened.

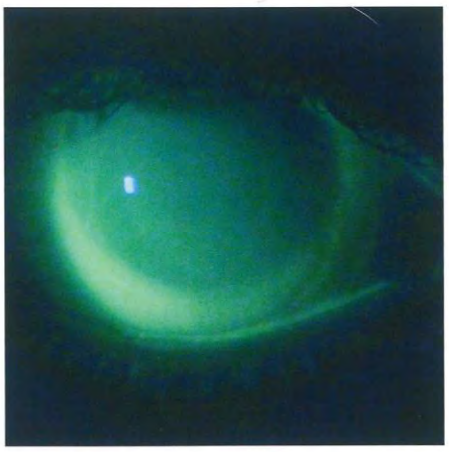

Figure 3. Fluorescein pattern of a KATT miniscleral. Note the even clearance over the limbal area.

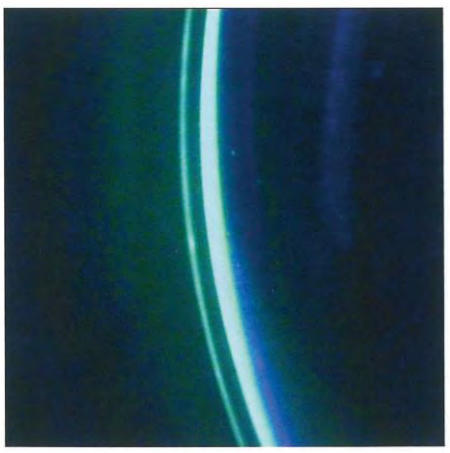

Figure 4. A narrow slit section showing limbal clearance

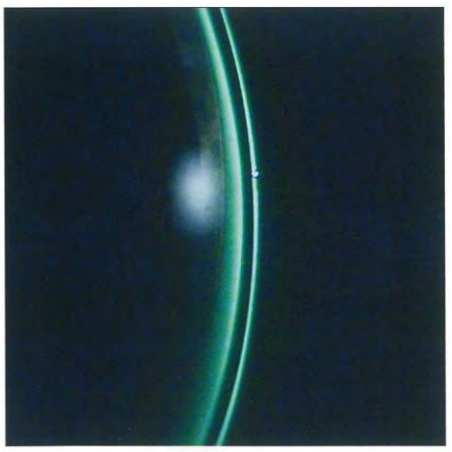

Figure 5. A narrow cross-section showing the apical clearance, which is equal to the lens thickness (0.30 mm)

Figure 6 shows the peripheral clearance of the lens using an OCT. Note the distinct clearance over the limbal stem cell zone and the peripheral curve that meets the sclera.

To date, over 40 patients have been fitted with this lens and the early results are very positive. Patients who were unsuccessful with the older miniscleral design have been refitted successfully, and we have noted a marked improvement in the ease of removal and a reduction in the post-removal rebound hyperaemia. The KATT (kerectasia alignment tangent torus) lens is simple to fit for the majority of eyes, but has the sophistication to be altered to cover all the variables. It is available from Capricornia Contact Lenses and is made from Boston XO2 material. ■

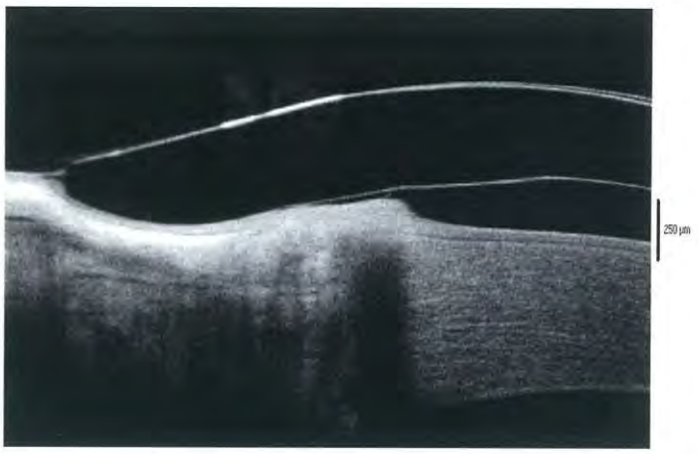

Figure 6. An Opto-Vue OCT section showing the peripheral clearance and edge curve of the lens on eye