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

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

of the joystick until the slit beam is focused on the cornea.

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 $CB_1 C_1$ is also known ($= 60^\circ$).

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:

$$\sin 60^\circ = \frac{CC_1}{CB_1} \quad \text{or} \quad CB_1 = \frac{CC_1}{\sin 60^\circ}$$

Now $\sin 60^\circ$ is 0.866. Thus, with a slit length of, say, 2 mm, the anterior chamber depth should be

$$\frac{2}{0.866} = 2.309.$$

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:

$$\frac{\text{Goldmann readings}}{\text{Slit lengths}} = 1.395.$$

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	+0.1187
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	+0.0978
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	2.7978	+0.0478
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. $\bar{x}$ mean = 1.82661. $\bar{y}$ 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:

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

Substituting these figures we have:

$$\text{Calculated Goldmann reading} = (1.117 \times \text{slit reading} + 0.5079).$$

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, $G = SL \times 1.1 + 0.5$, 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.

References

- Bleeker, G. M. (1960). Serial recording of the depth of the anterior chamber. *Archives of Ophthalmology*, **63**, 821–830.
- Bleeker, G. M. (1961). Evaluation of three methods of recording the anterior chamber depth of the eye. *Archives of Ophthalmology*, **65**, 369–374.
- Brown, N. (1973). Quantitative Slit-Image Photography of the anterior chamber. *Transactions of the Ophthalmological Societies of the United Kingdom*, **93**, 277–286.
- Heim, M. (1941). Photographische Bestimmung der Tiefe und des Volumens der menschlichen Vorderkammer. *Ophthalmologica*, **102**, 193–220.
- Jaeger, W. (1952). Tiegennessung der menschlichen Vorderkammer mit plan parallelen platttern. (Zusatzgerät zur Spaltlampe). *Albrecht v. Graefes Archiv für Ophthalmologie, vereinigt mit Archiv für Augenheilkunde*, **153**, 120–131.
- Lindstedt, F. (1916). Über die messung der Tiefe der vorderen Augenkammer mittels eines neuen, für klinischen Gebrauch bestimmten Instruments. *Archiv für Augenheilkunde*, **80**, 104–167.
- Lowe, R. F. (1968). Time-amplitude ultrasonography for ocular biometry. *American Journal of Ophthalmology*, **66**, 913–918.
- Stenstrom, S. (1953). An apparatus for the measurement of the depth of the anterior chamber based on the principle of Lindstedt. *Acta Ophthalmologica*, **31**, 265–270.