Anterior lens displacement with age

RONALD F. LOWE

From the Glaucoma Unit, The Royal Victorian Eye and Ear Hospital, Melbourne, and the Ophthalmic Research Institute of Australia

A slight anterior displacement of the lens with age was first postulated by Raeder (1922). Using a new ophthalmophakometer, he measured the positions of the anterior and posterior lens surfaces relative to the cornea. By graphing the means of the measurements within successive age groups he constructed regression lines for the position of the two lens surfaces against age, but no tests for statistical significance were applied.

In particular, Raeder used the age range from 25 to 65 years and found during that time:

- (1) A mean decrease of anterior chamber depth of 0.47 mm.
- (2) A mean increase of lens thickness of 0.81 mm.
- (3) A forwards displacement of the anterior lens surface of 0.33 mm.
- (4) A backwards displacement of the posterior lens surface of 0.20 mm.

All these figures cannot be reconciled, but comparing (1) and (2) together and then (3) and (4) together, a slight anterior lens displacement with age is indicated.

Raeder's graph for age *v.* posterior lens surface position looks unsatisfactory, and Raeder admitted that the posterior lens measurements were less exact than the anterior.

Raeder's observations of lens displacement with age have attracted very little interest over the years (Calmettes, Deodati, Huron, and Béchac, 1958; Weale, 1962), and his examinations do not appear to have been repeated.

With time-amplitude ultrasonography the positions of the various interfaces in the eye can be readily measured. The detailed procedure and the accuracy of the method have been previously described (Lowe, 1967, 1968).

Technique and subjects

Eighty people with normal eyes, 57 females and 23 males, aged between 30 and 85 years (mean 61.2), were referred from the hospital's outpatient department. Most had attended for presbyopic corrections and none had high refractive errors although they were not selected for emmetropia. Both eyes were used as a means of cross-checking the technical aspects of the procedures, but tests from three eyes were rejected because of unsatisfactory recordings. These 157 normal eyes were the same as those used for other tests previously reported (Lowe, 1967, 1968, 1969a, b, c). Pupils were dilated with 2 per cent. homatropine and cocaine eyedrops.

15 MHz time-amplitude ultrasonography with a stand-off technique was used (Lowe, 1967). The method has been shown to be sufficiently accurate for biometric population studies (Lowe, 1968).

Results

These are summarized in the Table.

Table Summarized statistics for age (X) v. various parameters (Y) of 157 normal eyes

Parameter (Y)	Regression line slope	Change in 50 years (mm.)	Analysis of variance		
			F- ratio	Probability	Significance
Central corneal thickness	+0.0002	+0.01	1.17	0.70 > P > 0.90	not
Mean corneal radius	-0.0005	-0.025	0.100	> 0.50	not
Axial length	-0.00085	-0.04	0.030	≥ 0.50	not
Anterior chamber depth	-0.013	-0.65	47.01	> 0.9995	extremely
Half lens thickness	+0.0073	+0.365	80.45	> 0.9995	extremely
Lens thickness + vitreous length	+0.011	+0.55	7.30	0.99 > P > 0.995	extremely
Corneal thickness + anterior chamber depth + lens thickness	+0.0017	+0.085	0.93	0.50 > P > 0.70	not
Vitreous length	-0.0025	-0.125	0.29	≥ 0.50	not
Anterior chamber depth + half lens thickness	-0.0025	-0.125	1.86	0.70 > P > 0.90	not

Corneal thickness, corneal radius of curvature, and axial length showed no significant change with age (Lowe, 1969a, b, c), so that the corneal surfaces and "retina" could be considered fixed reference points for measurements of the lens changes.

" t "-tests were applied to selected pairs of regression coefficients of appropriate parameters (Y) against age (X) in order to compare the magnitudes of the two factors with increasing age. The signs of the regression coefficients were neglected in these tests.

The position of anterior lens surface in relation to age was measured from two directions—the distance from back of cornea to front of lens (anterior chamber depth) and the distance from front of lens to retina (lens thickness + vitreous length) (Table). A " t "-test showed no significant difference between the magnitudes of the two regression coefficients ($t = 0.410$; degrees of freedom = 310). The mean decrease in anterior chamber depth for 50 years was 0.65 mm. which was not statistically different from 0.55 mm. for the mean increase in the distance from anterior lens surface to retina.

The mean change in posterior lens surface position in relation to age was also measured in two directions—the distance from front of cornea to back of lens (corneal thickness + anterior chamber depth + lens thickness) and the distance from back of lens to retina (vitreous length) (Table). A " t "-test showed no significant difference between the magnitudes of these two regression coefficients ($t = 0.853$; degrees of freedom = 310).

The mean change in posterior lens position in 50 years was 0.085 mm., measured from the front of the cornea to the back of the lens, which showed no statistical difference from 0.125 mm. measured from back of lens to retina.

Biomicroscopy and histology show that the lens grows symmetrically antero-posteriorly. If there were no change in lens position with age, the shallowing of anterior chamber depth should be equal to half the increase in lens thickness. A " t "-test was applied to the magnitudes of the paired regression slopes of age v. anterior chamber depth, and age v. half lens thickness (Table). A highly significant difference was found ($t = 2.75$; d. of f. =

310; 0.97 > P > 0.999). The regression slopes show that anterior chamber depth decreases more quickly than half lens thickness increases, indicating another factor in addition to lens thickness as a cause of diminishing anterior chamber depth. Comparison of the rates of change shows that the additional factor has less influence on anterior chamber depth than the lens growth.

Likewise a "t"-test applied to the magnitudes of the regression slopes for age *v.* half lens thickness, and age *v.* corneal thickness + anterior chamber depth + lens thickness (position of posterior lens surface) (Table) showed an extremely significant difference ($t = 2.88$; d. of f. = 310; 0.995 > P > 0.999).

The change in the position of the posterior lens surface is not equal to half the additional lens thickness but is considerably less (Table) because the posterior displacement of the posterior lens surface that would be produced by lens growth is reduced by another factor (anterior lens displacement).

Thus, the position of the anterior lens surface moved more anteriorly than half the increase in lens thickness caused by lens growth, and the position of the posterior lens surface moved less posteriorly than half the increase in lens thickness caused by lens growth.

Finally, a "t"-test was applied to the magnitudes of the regression slopes for age *v.* anterior chamber depth, and age *v.* vitreous length. An extremely significant difference was found ($t = 4.35$; d. of f. = 310; 0.999 > P). The regression slopes showed that with age the position of the anterior lens surface (anterior chamber depth) was changing much faster than the position of the posterior lens surface (vitreous length).

The distance of anterior chamber depth + half lens thickness was measured as an indicator of central lens position. This is a more difficult and less exact calculation than the measurements of the other distances because it involves combining two separate ultrasonic measurements, one of which is obtained by halving the distance between two ultrasonic reflexes. The change was found to be -0.125 mm. for 50 years and although the change in direction (forwards) is consistent with the previous figures, the slope of the regression line failed to achieve statistical significance. This lack of statistical significance is not surprising in view of the relatively small amount of lens displacement in 50 years in relation to the measuring method.

Comment

Slit-lamp examination and histological experience show an equal antero-posterior growth of the lens during adult life and not a crowding of the new lens fibres into the anterior portion of the lens. The figures in the Table show a considerably increased change in the position of the anterior lens surface compared with the posterior lens surface (0.65 mm./0.13 mm. in 50 years). These figures indicate 0.2 mm. anterior displacement of mid-lens position in 50 years, which is within clinical range of the figure of 0.125 mm. shown in the Table.

Discussion

Cause of anterior lens movement with age

Priestley Smith (1883) was the first to demonstrate conclusively the overall increase in lens size throughout life. The lens growth he postulated is no longer disputed.

The zonule must be a relatively inelastic structure to convert ciliary body changes into alteration of lens form. During accommodation, the lens is displaced slightly by gravity,

and anterior lens movement is very marked following zonulolysis before cataract extraction. Likewise, increase of equatorial diameter and antero-posterior thickness of the lens with age can be expected to cause a slackening of the zonule which could be taken up by anterior lens displacement.

Clinical conditions

The investigations described in this paper were undertaken to determine if anterior lens movement with age might have any significant role in the production of the shallow anterior chambers of primary angle-closure glaucoma.

In a lifetime, the change in lens position is very small in relation to the mean difference of 1.0 mm. between the anterior chamber depths of normal eyes and eyes with primary angle-closure glaucoma. Normal anterior lens displacement with age would not be a factor in causing the shallow anterior chamber of eyes affected with primary angle-closure glaucoma except in exceptional cases in some very elderly people where the lens displacement could be added to the other lens factors (Lowe, 1969a).

Weale (1962) has discussed the effects on physiological optics of anterior lens movement with age.

Accuracy of measurements

Anterior chamber depths have been measured by a large number of investigators and regression lines for decrease of anterior chamber depth with age have been given by Raeder (1922), Rosengren (1931, 1950), Törnquist (1953), Calmettes and others (1958), Weekers, Grieten, and Laverigne (1961), Luyckx-Bacus and Weekers (1966), and Lowe (1968). Their results are surprisingly inconsistent. Part of the differences probably depend upon variations in population samples. Most authors stated their patients were emmetropic, but this state is difficult to define in elderly people. Part of the differences probably depend upon different instrumentation as well as errors from the calculations which are based on standard eyes.

Time-amplitude ultrasonography has considerable advantages over optical methods for measuring lens size and position in that mathematical assumptions are less and the position and thickness of the lens can be plotted simultaneously. A limiting factor is the relatively coarse ultrasonic wave-form compared with light.

Ultrasonic ocular biometry is now being used extensively and some large examination series are being compiled. With large numbers and refinements in technique, the results may become more accurate and the small anterior lens movement with age may be capable of more definite direct measurement.

Summary

Ultrasonic biometry indicates a small anterior displacement of the lens with advancing age throughout adult life. The change in lens position is approximately 0.2 mm. in 50 years. Normal anterior lens displacement has very little significance for primary angle-closure glaucoma.

These investigations formed part of Research Projects No. 13 of The Royal Victorian Eye and Ear Hospital, and No. 14 of The Ophthalmic Research Institute of Australia, and were conducted in the Glaucoma Unit of the Hospital. Valuable clinical and technical assistance was given by Dr. Magda Horvat, and the statistics were analysed by Mr. Kenneth Shankly M.Sc. with the computer in the Biophysics Section of the Physiology Department of the University of Melbourne. Mrs. G. Heinze translated Raeder's paper.

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