Radius of curvature of the anterior lens surface

Correlations in normal eyes and in eyes involved with primary angle-closure glaucoma

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Recent papers have presented correlations between the radius of curvature of the anterior lens surface and anterior chamber depth (Lowe, 1972), and between the anterior lens radius and the anterior and posterior corneal radius (Lowe and Clark, 1973). This paper presents measurements of anterior lens radius in relation to age, lens thickness, and axial length in two series comprising 91 normal eyes and 91 eyes involved with primary angle-closure glaucoma. The examinations were conducted at the same times, in the same manner, and on the same subjects as those described in the previous two papers.

Results

Change of radius of anterior lens surface with age

For the series of 91 normal eyes with an age range of 23 to 77 years (mean 61.4) and for the 91 eyes involved with primary angle-closure glaucoma with an age range of 35 to 83 years (mean 63.5), anterior lens radius was statistically, but negatively, correlated with age (increasing anterior lens curvature with increasing age—curvature being the reciprocal of radius) (Table, overleaf).

Relation of anterior lens radius to lens thickness

As age has a significant effect upon both anterior lens radius and lens thickness, correlations between the two measurements were calculated for the full age range, and then for the decade 60 to 69 years, which decade contained the largest numbers in both series of eyes. With each of the calculations a high negative correlation was found between anterior lens radius and antero-posterior lens thickness (increasing anterior lens curvature with increasing lens thickness) (Table).

Relation between anterior lens radius and axial length

Over the whole age range, and in the decade 60 to 69 years, a highly significant positive correlation was found between anterior lens radius and axial length (decreasing anterior lens curvature with increasing axial length) (Table).

Table Correlation between measurements of radius of curvature of anterior lens surface and other parameters

Series of eyes		Normal (age range 23-77 yrs)				
<i>Y factor</i>	<i>X factor</i>	<i>No.</i>	<i>Regression line, Y=</i>	<i>Correlation coefficient (r)</i>	<i>Probability P</i>	<i>Significance</i>
Anterior lens radius	Age	91	$-0.0551X + 13.756$	-0.3576	$P < 0.001$	Highly
Anterior lens radius (all ages)	Lens thickness (ultrasonic)	91	$-3.237X + 24.717$	-0.6991	$P \leq 0.001$	Very highly
(60-69 yrs)	Lens thickness (ultrasonic)	42	$-3.033X + 24.013$	-0.6155	$P \leq 0.001$	Very highly
Anterior lens radius (all ages)	Axial length (ultrasonic)	91	$1.141X - 16.002$	0.5675	$P \leq 0.001$	Very highly
(60-69 yrs)	Axial length (ultrasonic)	42	$0.783X - 7.703$	0.4911	$P < 0.001$	Highly

Discussion

Anterior lens curvature with age

At least since the time of Donders (1864), the frequent slow development of hypermetropia after middle age has been attributed to a hardening of the outer layers of the lens accompanied by a progressive flattening of the anterior lens surface. These two components are quoted throughout the literature, various authors giving more emphasis to the one or the other factor.

Slit-lamp observations which showed the outer bands of discontinuity to be wider towards the equator and narrowed at the axis were used to support the hypothesis of flattening (increased radius) of the anterior lens surface supposedly resulting from increased thickness of the lens from its continued growth. However, the bands of discontinuity cross cell boundaries and are optical phenomena unrelated to cellular morphology within the lens (Lowe, 1949). Despite a century's repetition of the hypotheses of developing hypermetropia, no measurements of the surfaces of the lens have been used to substantiate these opinions.

We could find no extensive series of measurements of anterior lens curvature compared with age except those of Nakajima (1968), and Nakajima, Kimura, Kitamura, Uesugi, and Handa (1968), who reported a significant increase in anterior lens radius with age (but gave no details of their statistics of regression).

It was with some surprise, therefore, that we found a decrease in anterior lens radius (increased curvature) with increasing age in adult life. The statistical significance was very high for the normal eyes and firmly significant for the eyes selected by their involvement with primary angle-closure glaucoma. (The selection of eyes by primary angle-closure glaucoma depends on physical conditions of the lens underlying pupil block).

Figs 1 and 2 show a wide scatter about the regression line and indicate weakness in assessing changes due to age based upon single observations in a series of different subjects. The more difficult and more convincing longitudinal observations over extended time will, of necessity, have to be left to other observers, but now that anterior lens measurements can be more readily obtained (Brown, 1972; Clark and Lowe, 1973), we hope that other investigators will reduce the uncertainties in the opposing results obtained by Nakajima and his colleagues and by us. For our calculations we used a different system, which we believe

using the method of least squares

With primary angle-closure glaucoma (age range 35-83 yrs)				
No.	Regression line, $Y=$	Correlation coefficient (r)	Probability P	Significance
91	$-0.0281X + 9.848$	-0.3125	$0.001 < P < 0.01$	Significant
91	$-1.317X + 14.560$	-0.5236	$P \ll 0.001$	Very highly
35	$-1.602X + 15.841$	-0.4627	$0.001 < P < 0.01$	Significant
91	$0.367X - 0.0167$	0.3787	$P < 0.001$	Highly
35	$0.675X - 6.918$	0.6033	$P < 0.001$	Highly

FIG. 1 Regression line for age (x) v. radius of anterior lens curvature (y) for 91 normal eyes (age range 23-77 years)

FIG. 2 Regression line for age (x) v. radius of anterior lens curvature (y) for 91 eyes involved with primary angle-closure glaucoma (age range 35-83 years)

to be more accurate, and the validity of our method was checked on both models and human eyes (Clark and Lowe, 1973). Our results oppose the hypothesis of decreasing curvature (flattening) of the anterior lens surface during adult life and do not substantiate it as a cause for the increasing hypermetropia of middle age.

Anterior lens curvature and lens thickness

Thickness of the lens is determined by at least two major influences:

- (a) Coordination with general eye form favouring emmetropia—almost certainly from polygenic inheritance;
- (b) Continued growth of the lens throughout life.

The radius of the anterior lens surface was compared with lens thickness in the decade 60 to 69 years, and over the full age range of the subjects. In normal eyes a high negative correlation was found for both groups. This suggests a high positive correlation between lens thickness and anterior lens curvature (the thicker the lens the greater the anterior curvature), basically constitutional and continuing with lens growth in adult life.

Similar conditions were found in eyes involved with primary angle-closure glaucoma, even though these eyes were statistically complicated by selection involving lens thickness.

Anterior lens curvature and axial length

In both series of eyes, over the whole age range and for the decade 60 to 69 years, anterior lens radius was statistically highly correlated with axial length—the longer the eye the less (the flatter) the curvature of the lens surface.

Conclusions

All the findings reported herein are consistent with the idea that the thicker the lens, whether constitutional or from age, the greater the curvature of the anterior lens surface.

The radius of the anterior lens surface is coordinated with other physical components of the optical system of the eye—with anterior corneal radius (positive) (Lowe and Clark, 1973), with posterior corneal radius (positive) (Lowe and Clark 1973), with anterior chamber depth (positive) (Lowe, 1972), with lens thickness (negative), and with axial length (positive) although the correlations vary considerably in strength.

Summary

Radius of curvature of the anterior lens surface was compared with age, lens thickness, and axial length in a series of normal eyes and a series of eyes involved with primary angle-closure glaucoma. Negative correlations were found between anterior lens radius with age and lens thickness, while a positive correlation was found for anterior lens radius with axial length.

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