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Posterior corneal curvature

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

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Measurements of the radius of curvature of the anterior surface of the cornea were facilitated by the ophthalmometer of Helmholtz of 1856, and became part of clinical practice following modifications in the principle and design of the instrument by Javal and Schiötz in 1881. Many studies have been published concerning anterior corneal curvature, but there is an extreme dearth of information pertaining to measurements of posterior corneal curvature.

As long ago as 1832, Krause measured eight eyes, but Helmholtz wrote that Krause's method did not seem to be sufficiently trustworthy.

Gullstrand (Southall, 1924) and Tscherning (1924) found they could not measure posterior corneal curvature in the centre owing to interference by the first Purkinje image, so they calculated the radius of the posterior corneal surface from measurements at the sides. Each measured only three eyes. These few appear to be the only measurements reported in the literature.

Whereas the bright first Purkinje image can be readily used for anterior keratometry, the second Purkinje image reflected by the posterior corneal surface is faint and much less well defined.

A different method of measurement has become available since the development of slit lamps with pachymeters and photographic attachments, and the use of computers to facilitate extensive mathematical calculations (Clark and Lowe, 1973). This paper describes measurements on 185 eyes.

Method

The radius of curvature of the anterior corneal surface was measured with a Haag-Streit keratometer. Photographs of corneal sections in the vertical meridian were matched against graticules containing curves of sequentially differing radii. Photographic radius of curvature of the posterior corneal surface was converted to true radius of curvature by skew ray tracing and an appropriate computer programme (Clark and Lowe, 1973). Further clinical details have been published previously (Lowe, 1972). By this technique, curved surfaces centred over a 5-mm. chord could be measured in the vertical meridian.

Subjects

Corneal measurements formed part of the examinations of 93 eyes of 48 patients who had had various types of primary angle-closure glaucoma, and 92 eyes of 46 people of similar age and sex distribution but with normal eyes. They were the same subjects more fully described in a previous paper reporting anterior lens curvatures (Lowe, 1972).

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Results

Mean corneal radius of curvature (vertical meridian)

The relationships of the mean of the anterior corneal radii to the mean of the posterior corneal radii for normal eyes is 7·65 to 6·46 mm., while the relationships in eyes involved with primary angle-closure glaucoma is 7·55 to 6·23 mm. (Table I). The means of the posterior corneal radii are statistically significantly less than the means of the anterior corneal radii (Table II).

Table I *Statistics of anterior and posterior corneal radii measured in the vertical meridian*

Corneal radius (mm.)	*Anterior*		*Posterior*	
Series of eyes	*Normal*	*Angle-closure glaucoma*	*Normal*	*Angle-closure glaucoma*
No. of eyes	92	93	92	93
Mean radius	7·65	7·55	6·46	6·23
Standard deviation	0·27	0·27	0·26	0·34
S.E. of mean	0·028	0·027	0·027	0·035
Range (mm.)	7·05–8·18	7·03–8·34	5·88–7·24	5·28–7·03

Table II *Results of 't' test on comparison of means of various corneal measurements*

Comparisons	*Degrees of freedom*	*'t' value*	*Probability of no difference*	*Significance*
Anterior corneal radius *v.* Posterior corneal radius				
(normal eyes)	182	29·97	P⩽0·001	High
(angle-closure glaucoma)	184	29·17	P⩽0·001	High
Posterior corneal radius (normal eyes) *v.* Posterior corneal radius (angle-closure glaucoma)	183	5·051	P⩽0·001	High
Anterior corneal radius (normal eyes) *v.* Anterior corneal radius (angle-closure glaucoma)	183	2·550	0·005 < P < 0·01	Significant

Comparison between radius of anterior corneal surface and radius of posterior corneal surface in the vertical meridian shows an extremely significant correlation within each group (Table III). Posterior corneal radii are approximately 1·2 mm. less than anterior corneal radii for normal adult eyes, and approximately 1·3 mm. less for eyes previously involved with primary angle-closure glaucoma.

There is a significant difference between the means of averaged anterior corneal radii of normal eyes and those affected by primary angle-closure glaucoma (Törnquist, 1957; Grieten and Weekers, 1962; Lowe, 1969a). In the present series, when only the vertical corneal meridian is considered, a significant difference is found between the means of the anterior corneal radii of the two groups (Table II).

For posterior corneal radii an extremely significant difference was found between the mean for the normal eyes and the mean for the eyes that had been involved with primary angle-closure glaucoma (Table II). Although the means were significantly different, there was considerable overlap by individual measurements from the two groups.

Correlation with corneal thickness

In previous studies (Lowe, 1969b; Tomlinson, 1972), no correlation was found between mean radius of anterior corneal surface and central corneal thickness, and in the present investigations no correlation was found between anterior corneal radius in the vertical meridian and central corneal thickness for either group (Table III). Nor was a correlation found between radius of posterior corneal surface (in the vertical meridian) and central corneal thickness (Table III, opposite).

Correlation with axial length

The mean of averaged radii of anterior corneal surface is very highly significantly correlated with axial length for both normal eyes and those involved with primary angle-closure glaucoma (Lowe, 1969c). In the vertical meridian, the radii of both corneal surfaces are very highly significantly correlated with axial length in both groups of eyes (Table III).

Correlation with age

Previously (Lowe, 1969a) no correlation was found between mean radius of anterior corneal curvature and age, after 30 years of age. In the present series, no correlation was found between posterior corneal radius and age during adult life in either group of eyes (Table III).

Effects of age

The normal subjects had an age range of 23 to 77 years (mean 61·4) and the patients previously involved with angle-closure glaucoma had an age range of 35 to 83 years (mean 63·15). In adult life, age has no significant effect upon corneal thickness (Lavergne and Kelecom, 1962; Lowe, 1969b), posterior corneal radius of curvature (Table III), or axial length (Luyckx-Bacus and Weekers, 1966; Lowe, 1970); but it has a very highly significant effect upon anterior chamber depth (Rosengren, 1931; Weekers, Grieten, and Lavergne, 1961; Lowe, 1968), lens thickness (Smith, 1883; Luyckx-Bacus and Weekers, 1966; Lowe, 1969c), and anterior lens curvature (Nakajima, 1968).

Correlations with posterior corneal radius and these changing parameters were calculated for the whole age range of the subjects in the present investigations, but in order to minimise the effects caused by age the correlations were also calculated for those in the decade 60 to 69 years (in which most of those in the present series were classed). However, this incurred a disadvantage in reducing numbers.

Correlation with true anterior chamber depth

Comparisons between mean radius of anterior corneal surface and anterior chamber depth have lacked significant correlation (Stenström, 1946; Lowe, 1969a). For the normal subjects correlation between posterior corneal radius and anterior chamber depth showed significance over the whole age range, but this significance was lost when the comparisons were made with the smaller number in the decade 60 to 69 years (Table III).

For the eyes involved with primary-angle closure glaucoma, comparisons between posterior corneal radius and anterior chamber depth lacked significance for both the total and restricted ranges of age (Table III).

Table III *Correlations between measurements of various ocular features, using the method of least squares, in a series of normal eyes and a series of eyes involved with primary angle-closure glaucoma*

Series of eyes		*Normal (Age range 23–77 yrs)*					*Involved with primary angle-closure glaucoma (Age range 35–83 yrs)*				
Y factor	*X factor*	*No.*	*Regression line, Y=*	*Correlation coefficient r*	*Probability*	*Significance*	*No.*	*Regression line, Y=*	*Correlation coefficient r*	*Probability*	*Significance*
Anterior corneal radius	Posterior corneal radius	92	0·791X+0·409	0·8102	P≪0·001	Highly	95	0·978X−1·156	0·7681	P≪0·001	Very highly
Posterior corneal radius	Central corneal thickness	92	0·267X+6·230	0·0457	P≫0·1	Not	95	−0·111X+6·299	−0·0139	P≫0·1	Not
Posterior corneal radius	True anterior chamber depth (All ages)	92	0·225X+5·871	0·2971	0·001<P<0·01	Significant	95	0·0586X+6·132	0·07449	P≫0·1	Not
	(60–69 yrs)	42	0·0592X+6·302	0·1034	P>0·1	Not	37	0·0695X+6·054	0·1106	P≫0·1	Not
Posterior corneal radius	Lens thickness (All ages)	91	0·0116X+6·415	0·0169	P≫0·1	Not	93	0·0346X+6·062	0·0394	P≫0·1	Not
	(60–69 yrs)	42	0·212X+5·512	0·3292	0·01<P<0·05	Probable	37	−0·440X+8·343	−0·3167	P=0·05	Probable
Posterior corneal radius	Axial length	91	0·123X+3·621	0·4134	P≪0·001	Highly	93	0·155X+2·817	0·4701	P≪0·001	Very highly
Posterior corneal radius	Age (All ages)	91	0·00164X+6·365	0·0721	P>0·1	Not	93	0·0027X+6·060	0·08689	P≫0·1	Not
Anterior lens radius	Posterior corneal radius (All ages)	92	1·524X+0·517	0·2287	0·01<P<0·05	Probable	93	0·0866X+2·694	0·3001	0·001<P<0·01	Significant
	(60–69 yrs)	42	0·00213X+6·436	0·0163	P≫0·1	Not	35	0·230X+4·335	0·5786	P<0·001	Very highly
Anterior corneal radius	Corneal thickness	92	0·0581X+7·613	0·0097	P≫0·1	Not	95	0·885X+7·022	0·1401	P>0·1	Not
Anterior corneal radius (vert.)	Axial length	91	0·0813X+5·771	0·2620	P=0·01	Significant	93	0·135X+4·580	0·5127	P≪0·001	Very highly
Anterior corneal radius	Anterior lens radius (All ages)	92	0·113X+9·501	0·01729	P≫0·1	Not	93	1·243X−1·302	0·3363	P<0·001	Very highly
	(60–69 yrs)	42	−0·194X+11·972	−0·0273	P≫0·1	Not	35	1·608X−4·156	0·5410	P<0·001	Very highly

Correlation with lens thickness

Comparisons between posterior corneal radius and lens thickness lacked significant correlation unless variations caused by age were minimized. Because corneal radius is strongly correlated with axial length, and lens thickness is inversely correlated with axial length (Lowe, 1970), one might expect a negative correlation between posterior corneal radius and lens thickness. In the subjects aged between 60 and 69 years a probable negative correlation was found, unexpectedly, for the eyes involved with angle-closure glaucoma, but not for the normal eyes (Table III).

Correlation with radius of the anterior surface of the lens

In the full range of normal eyes, only a weak correlation was found between posterior corneal radius and anterior lens radius, but a stronger correlation was found for the eyes involved with primary angle-closure glaucoma (Table III). Within the restricted age range of 60 to 69 years, the significance of the correlations was enhanced.

Comparing anterior corneal radius and anterior lens radius, no correlation was found over the whole series or for the restricted age range in normal eyes (Table III), but the correlation for eyes involved with angle-closure glaucoma was very highly significant in both age ranges (Table III).

In both groups of eyes, the variances for anterior corneal radius were very similar, but those for anterior lens radius were almost four times greater for normal eyes than for eyes involved with primary angle-closure glaucoma. The closer correlations between anterior lens radius and both anterior and posterior corneal radius in the eyes involved with primary angle-closure glaucoma compared with normal eyes, possibly provides another indication of the importance of anatomical influences underlying primary angle-closure glaucoma.

Discussion

Except when involved with disease, the posterior corneal surface has received little attention. In ocular biometry its presence is either ignored or given scant attention; yet the posterior corneal surface is of considerable interest. Not only is it of physical importance in anterior chamber geometry, but it possesses individual biological significance (even though overshadowed by other ocular surfaces).

When matching photographed corneal curves against circular arcs etched in sheet plastic, the posterior corneal curves could be given a "best fit" much more readily than the anterior corneal curves.

Tomlinson (1972) discussed peripheral flattening of the anterior corneal surface as a cause of peripheral thickening of the cornea, but the periphery of the cornea is thicker than the centre not only because the posterior corneal radius is less than the anterior radius, but seemingly also because the periphery of the posterior corneal surface does not become so markedly aspheric as the anterior corneal surface. (We prefer the term "positive asphericity" to "flattening" (Clark, 1972).)

Calculations of the height of the corneal dome in relation to anterior chamber depth (Delmarcelle, Collignon-Brach, and Luyckx-Bacus, 1969) should involve the posterior corneal surface rather than the anterior (Storey and Phillips, 1971) even though the two curves are extremely closely correlated.

Despite the extremely close statistical correlation between the radii of the two corneal surfaces, some independence is maintained. This is shown by variation in the correlations between anterior and posterior corneal radii with other ocular measurements.

The Figure shows not only that the two corneal surfaces diverge as the periphery is approached, but that the posterior corneal surface and the anterior lens surface become closer at the periphery. In some cases of primary angle-closure glaucoma, the anterior lens curvature is considerably greater than the anterior corneal curvature, but in no case was the anterior lens curvature greater than the posterior corneal curvature. Correlation between posterior corneal radius and anterior lens radius was much more significant for the eyes selected by involvement with angle-closure glaucoma than for the normal eyes.

In addition to the shallowness of the anterior chamber, the convergence of the peripheries of the posterior cornea and the anterior lens would position the peripheral iris close to the peripheral cornea (as seen by slit-lamp examination) and thus contribute to the predisposition for angle closure not only from iris convexity from pupil block, but also from iris folding with pupil dilatation.

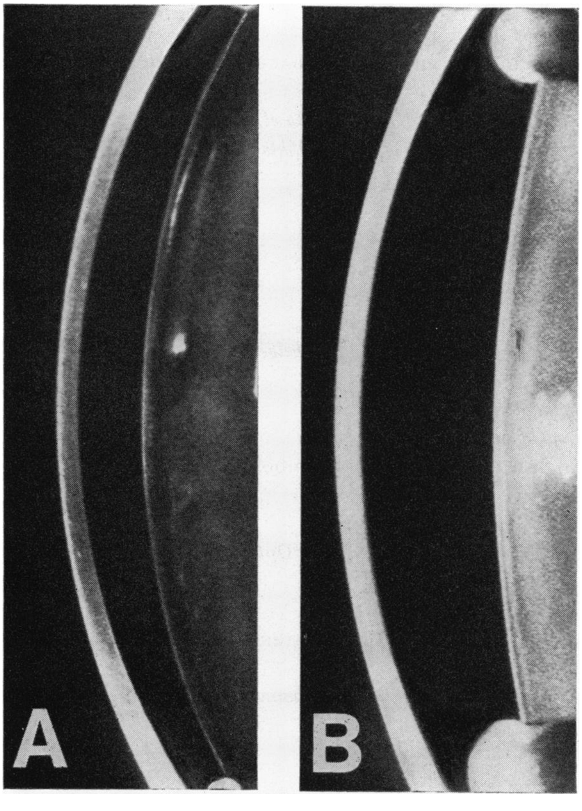

FIGURE *Slit-lamp photographs showing convergence of peripheries of posterior cornea and anterior lens*

Statistics	*Eye A*	*Eye B*
Sex	*F*	*F*
Age (yrs)	66	58
Type of eye	*Angle-closure glaucoma*	*Normal*
Anterior corneal radius (mm).	7·27	8·10
Posterior corneal radius (mm.)	5·85	6·90
Corneal thickness (mm.)	0·54	0·60
True anterior chamber depth (mm.)	1·40	2·54
Anterior lens radius (mm.)	7·09	11·84

Summary

The mean radius of the posterior corneal surfaces (measured in the vertical meridian) is 6·46 mm. (S.D. 0·26) for normal eyes, and 6·23 mm. (S.D. 0·34) for eyes previously involved with primary angle-closure glaucoma. These means are statistically different.

The radius of the posterior corneal surface is correlated with the radius of anterior corneal surface, and for axial length for eyes in both groups. Comparisons between posterior corneal radius and true anterior chamber depth showed unconvincing correlation for normal eyes but no correlation for glaucomatous eyes. Comparisons between posterior

corneal radius and anterior lens radius gave more significant correlations for the glaucomatous eyes than for the normal eyes.

Posterior corneal curvature is an anatomical factor that may have significance for primary angle-closure glaucoma.

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