Corneal thickness, astigmatism, and atopy

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SUMMARY Keratometry and regional pachometry were performed on atopic patients with no history or signs of atopic keratoconjunctivitis. In a series of 80 eyes there was a skewed distribution towards thinner corneas ($p < 0.01$) and a preponderance of against-the-rule astigmatism. The maternal age at birth of this group of patients was higher than that in the general population. These findings are discussed in the context of the known association of atopy with keratoconus.

The term 'atopy' was used by Coca and Cooke¹ to indicate a hypersensitivity response to common allergens which was subsequently found to be mediated by a specific class of immunoglobulin IgE.² Atopy is thus defined as the capacity to produce IgE (reaginic) antibodies to various common environmental allergens.³ Eczema, asthma, and hay-fever are the principal conditions within the group, but there is considerable variety and range of severity of manifestations among affected individuals.

The premise for this study is based on four observations. First, there is a high prevalence of atopy among patients with keratoconus^{4,5}; secondly, irregular corneal astigmatism is associated with keratoconus^{7,8}; thirdly, the slit-lamp signs, retinoscopy, and keratometry findings in keratoconus are preceded by corneal thinning⁹; fourthly, Kornerup and Lodin as part of their investigation of atopic cataract recorded a high prevalence of irregular corneal astigmatism.⁵

The aim of this study was to compare the thickness and curvature of the cornea in atopic patients without ocular disease with those in the normal population.

Material and methods

SELECTION OF PATIENTS

Subjects were selected from the respondents to an invitation to participate in a study of the cornea in atopy which was placed in the *Eczema Journal*, a quarterly publication of the Eczema Association, and from referrals from a dermatologist. Subjects with a history or signs of ocular disease, or who had ever worn contact lenses, were excluded. Atopy was

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diagnosed by a consultant physician. Eighty eyes were examined.

INVESTIGATIONS

A questionnaire was completed which detailed the ocular and atopic history of each subject and his/her immediate family. In view of the reported higher incidence of keratoconus among children of older mothers⁹ the maternal age at birth was recorded. After testing Snellen visual acuity, refraction, and a slit-lamp examination, corneal curvatures were measured with the American optical keratometer.

A modification of the Haag-Streit pachometer first suggested by Donaldson¹⁰ and modified by Mandell and Polse¹¹ was used for the measurement of corneal thickness centrally and at four midperipheral points. The conventional pachometer requires the subject to view the incident light beam with the microscope set obliquely (at 45°). Corneal thickness is thus measured along the visual axis only and does not permit an exact comparison between eyes, particularly if there is a large angle between the visual and geometric axes.¹² In order to reduce these errors measurements were taken at the geometric centre of the cornea.

To measure peripheral corneal thickness at the same distance from the optical centre in every eye the following system was used. The microscope is perpendicular to the cornea and the incident light beam strikes obliquely. For measurements on the geometric axis the subject fixates between two green light emitting diodes (LEDs) mounted in an acrylic plate (Fig. 1), and the microscope adjusted so that their corneal reflections are symmetrically disposed in the eyepiece. The four red LEDs, each of which subtends an angle of 14° to the cornea, serve as

Fig. 1 Light emitting diodes (LEDs) mounted in an acrylic plate and fixed to the housing of a Haag-Streit 900 slit-lamp. Open arrows=green LED; closed arrows=red LED which subtend an angle 14° to the geometric axis.

fixation points for midperipheral measurements of corneal thickness. This technique allows successive measurements of the same site on the cornea. A

potentiometer is coupled to the measuring shaft of the basic instrument to improve observer accuracy and to provide a digital read-out. Three readings were taken at each position and the mean figure taken.

The youngest patient was 12 years old, and, although attempts were made to measure younger patients, fixation was unsatisfactory. Those with poor fixation due to presbyopia were also excluded. One case of keratoconus was diagnosed from the respondents and excluded from the study.

Results

There were 20 male and 20 female subjects. Their atopic symptoms are shown in Table 1. The frequency distribution of maternal age at birth in the general population in 1960, which corresponds to the median birth year of the subject group, is given in Table 2. Paternal age was not recorded by the

Table 1 Additional atopic history

Asthma	62.5%
Hay-fever	62.5%
Food allergies	7.5%

Table 2 Frequency distribution: maternal age at birth: general population 1960

	<20	20-24	25-29	30-34	35-39	40-44	45-49	Total
No.	46 067	229 064	233 579	143 475	77 261	17 736	1315	748 498
%	6.15	30.50	31.21	19.17	10.32	2.37	0.18	100

Source: Registrar General's Statistical Review. London: Office of Population and Census Surveys, 1960.

Table 3 Frequency distribution: paternal age at birth: general population 1961

	<20	20-24	25-29	30-34	35-39	40-44	<45	Total
No.	621 000	305 000	234 900	151 000	77 000	35 000	16 300	1 480 200
%	43.10	21.18	16.30	10.48	5.30	2.43	1.13	100

Source: Registrar General's Statistical Review. London: Office of Population and Census Surveys, 1961.

Table 4 Frequency distribution: maternal age at birth: subjects

	<20	20-24	25-29	30-34	35-39	40-44	45-49	Total
No.	0	6	10	15	6	2	0	39
%	0	15.38	25.64	38.45	15.38	5.12	0	100

One subject adopted—maternal age not known.

Table 5 Frequency distribution: paternal age at birth: subjects

	<20	20-24	25-29	30-34	35-39	40-44	>45	Total
No.	0	3	10	12	7	3	3	38
%	0	7.89	26.31	31.57	18.42	7.89	7.89	100

Paternal ages not known in two cases.

Table 6 Frequency distribution of central corneal thickness (mm) in atopic subjects

CCT No.	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	>0.55
	2	3	7	14	11	13	18	10	Nil

CCT=central corneal thickness.

Number of eyes=78.

Mean central corneal thickness=0.514, SD 0.025 mm.

Table 7 Central corneal thickness in normal eyes

Author	Corneal thickness (mm $\pm$ SD)	No. of eyes	Year
Donaldson ¹⁰	0.522 $\pm$ 0.041	268	1966
Martola and Baum ¹⁸	0.523 $\pm$ 0.041	268	1966
Lowe ¹⁹	0.517 $\pm$ 0.034	157	1969
Kruse Hansen ¹²	0.520 $\pm$ 0.018	76 (R)	1971
Kruse Hansen ¹²	0.524 $\pm$ 0.02	74 (L)	1971

Number of eyes=784.

Mean central corneal thickness=0.521 mm.

Registrar General until 1961 (Table 3), which precludes strict comparative analysis. The frequency distribution of maternal and paternal age at birth of the subjects is shown in Tables 4 and 5. Eighty eyes had corneal thickness measurements taken at five points. The measurements were taken at the geometric centre of the cornea and at four points corresponding to a rotation of the eye by 14°. Results were discarded from one patient as being unreliable owing to poor fixation.

CENTRAL CORNEAL THICKNESS

The frequency distribution for central corneal thickness for the 78 remaining eyes is given in Table 6. The mean value was 0.514 mm. Measurements of central corneal thickness in normal eyes are given in Table 7, with a mean value of 0.521 mm. Kruse Hansen found a difference between right and left eyes which was

Fig. 2 Distribution of central corneal thickness in eyes of atopic patients.

thought to be due to the technique being susceptible to a different measurement on the two eyes owing to angle kappa.¹²

All authors reported that in healthy eyes corneal thickness is Gaussian in distribution.¹²

Plotting the findings for this study indicated that the distribution in the atopic group might not be Gaussian (Fig. 2). The results were therefore submitted to statistical analysis. An appropriate analysis is the χ^2 goodness of fit test, where observed frequencies are compared with expected frequencies for a normal distribution (Table 8).

For eight classes there are 6 degrees of freedom. Critical χ^2 with df 6 at $p=0.05$ is 12.59, which is just larger than the result found (12.58). Although at $p=0.05$ there is not a statistically significant deviation from a normal distribution, for $p=0.10$ $\chi^2=10.67$ it is significant. If the sample had been increased to 105 eyes, it might have proved significant at $p=0.05$.¹³

MID PERIPHERAL CORNEAL THICKNESS

The results for midperipheral corneal thickness accorded with those of other workers.¹⁴ However, in four eyes the thinnest reading was from one of the midperipheral points rather than the centre. One of these showed slight irregularity of keratometer mires; the other three were regular. Two had a visual acuity of 6/5 and two 6/12.

CORNEAL CURVATURE

Keratometry was performed satisfactorily on 80 eyes. These results were then analysed into four classes: (1) against-the-rule astigmatism; (2) with-the-rule astigmatism; (3) spherical; (4) oblique astigmatism.

Table 8 χ^2 goodness of fit test for central corneal thickness in atopes

Range	Observed	Expected	(Observed-expected) ²	χ^2
<0.475	2	4.633	-4.594 ²	9.594
0.475 to 0.485	3	4.691	-1.961 ²	4.691
0.485 to 0.495	7	7.846	-0.846 ²	7.846
0.495 to 0.505	14	10.592	3.408 ²	10.592
0.505 to 0.515	11	12.215	-1.215 ²	12.215
0.515 to 0.525	13	12.012	0.988 ²	12.012
0.525 to 0.535	18	10.101	7.899 ²	10.101
0.535 to 0.545	10	7.254	-5.639 ²	15.639
>0.545	0	8.385		
Total				12.5751

Table 9 Corneal astigmatism in normal eyes¹⁶

	Before age 25 (n=1018)	After age 50 (n=1025)
Against	24 (2.35%)	118 (11.51%)
With	910 (89.39%)	737 (71.9%)
Spherical	52 (5.10%)	84 (8.19%)
Oblique	32 (3.14%)	86 (8.39%)

Table 10 Corneal astigmatism: atopic subjects

Against	=44	55%
With	=11	13.75%
Spherical	=17	21.25%
Oblique	= 8	10.00%

Mean age=24.28. Standard deviation=10.54. No.=80.

Against-the-rule astigmatism was considered to be present when the flatter corneal meridian lay within 15° of the vertical and with-the-rule when the steeper corneal meridian lay within 15° of the vertical. This is similar to the classification used by Duke-Elder¹⁵ and Borish.¹⁶

Corneae were classified as spherical when the difference in radii of curvature between the two principal corneal meridians was 0.04 mm or less. The accuracy of measuring the axis of corneal astigmatism decreases as the difference in corneal curvature between the two meridians decreases.

Where the principal corneal meridians lay more than 15° from the vertical or horizontal, the cornea was classified as oblique. Corneal astigmatism in normal persons and the atopic group are given in Tables 9 and 10.

Discussion

The finding of Kornerup and Lodin⁵ that there is a higher prevalence of irregular corneal astigmatism was not confirmed, but a significant variation from the normal population was found when the axis of the flatter corneal meridian was observed.

Corneal thickness measurements showed a significant variation from the norm at $p=0.1$, very nearly significant at the $p=0.05$, and a larger sample may have confirmed this. The skewedness of the variation was towards thinner corneae, as can be seen from Fig. 2.

Tables 2 and 4 show a higher percentage of older mothers in the subject group compared with the general population born in 1960, which corresponds to the median birth year of the subject group. Paternal age was not recorded by the Registrar General until 1961, and therefore an exact comparison with the subject group is not possible. Further-

more, parental age is recorded only for legitimate births, which comprised 86% of total births in 1961. With this proviso, however, it can be seen from Tables 3 and 5 that there is a high percentage of older fathers in the subject group.

These three findings of against-the-rule astigmatism, corneae thinner than normal, and higher maternal age at birth parallel the findings in patients with early keratoconus.¹⁷ It has long been established that patients with keratoconus have against-the-rule myopic astigmatism at presentation which may progress to irregular astigmatism. However, in this group all but one subject had normal vision either unaided or with spectacles and had none of the additional features of keratoconus.

Furthermore the distribution of corneal thicknesses in the subjects is similar to those with established early keratoconus.⁹ Thus, together with the maternal age findings, it could be postulated that the subjects in the study represent a point on the continuum of corneal variation whose extreme presentation is keratoconus.

It is accepted that some subjects were self-selecting in that they responded to an advertisement in the *Eczema Journal* and the resulting sample for study is not necessarily unbiased.

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