A New Photogrammetric Method for Quantifying Corneal Topography

Kenneth L. Cohen,* Nancy K. Tripoli,* Alvin C. Pellom,†
Lawrence L. Kupper,‡ and Andrzej W. Fryczkowski*

Attempts to describe normal corneal shape and to represent corneal topography by an array of discrete points have limited usefulness. A quantitative photogrammetric method that produces indices to describe corneal shape was developed. Four indices depict the departure of keratographic rings from circularity, and two indices express the trends and consistencies of all the rings from one keratograph. This photogrammetric index method (PIM) was evaluated against established measurement techniques. Values for the six indices were computed for groups (10 corneas each) of symmetrical, regularly astigmatic, and keratoconic corneas that had been defined by keratometry and clinical criteria. Predictions of the differences among groups were formulated for each index based on group descriptions and anticipated manual tracing and/or digitization error. Parametric and nonparametric tests of significance supported most predictions. The asymmetry of irregularly astigmatic keratoconic corneas, the variability of their orthogonal principal meridians, and an increasing symmetry toward their peripheries were documented clearly. The circularity of symmetrical group rings and the ellipticity of regularly astigmatic group rings were also evident. Preliminary norms are offered to illustrate the usefulness of the PIM in defining groups of corneas with the same histories and in classifying individual corneas. Invest Ophthalmol Vis Sci 25:323–330, 1984

Investigations in the field of corneal topography have measured and observed the corneal surface to infer the shape of the normal cornea. Resulting knowledge of normal corneal topography has been conflicting and somewhat limited. A spherical central zone and a flatter peripheral zone have been accepted.[1] However, a more shallow annulus between zones, the rate of peripheral flattening, and the position of the optic zone are disputed.[1–5] Clearly the term, "normal cornea" encompasses a broad category of corneal shapes that interact with other optical components to produce normal human vision. These attempts to identify the normal corneal shape contribute little to the understanding of a single cornea or a group of corneas linked by a common history.

In an attempt to increase the clinical usefulness of corneal surface description, Rowsey used the corneascope and comparator developed by A. E. Reynolds to reconstruct an individual corneal profile as a two-dimensional data array of diopter values that corresponds to points along meridians on corneascopic ring reflections.[6] The relationship between these numerous discrete points must be analyzed in order to fully describe corneal topography. To arrive at diopter values that characterize a group of individual corneas, the principal astigmatic meridians of the corneas must be aligned so that the corneal astigmatism will be manifest in the group means. The individual corneascopic ring shapes of a group of irregularly astigmatic corneas cannot be represented by group means.

We have developed a method for quantitative photogrammetric analysis of corneal shape. This method allows corneas to be grouped and the regularly and irregularly astigmatic characteristics of a group to be represented by statistical indices. Using corneascopic photographs and the geometric properties of closed loops, numeric indices that represent the keratographic ring shapes as they depart from circularity and the pattern of ring shapes in an individual keratograph are produced. The resulting pattern of indices can describe the shape and astigmatic character of a single cornea or a group of corneas. This method does not attempt to assign a diopter power value to a specific corneal location. Our investigation attempts to determine if this photogrammetric method can describe and distinguish between symmetrical, regularly astigmatic, and

From the Departments of Ophthalmology,* Geography,† and Biostatistics,‡ University of North Carolina, Chapel Hill, North Carolina.

Supported by grant no. 1 R03 EY04344-01, from the National Eye Institute, National Institutes of Health, Bethesda, Maryland. Supported in part by a grant from the North Carolina Lions Association for the Blind, Inc., and Research to Prevent Blindness, Inc., New York, NY.

Submitted for publication: May 20, 1983.

No reprints available.

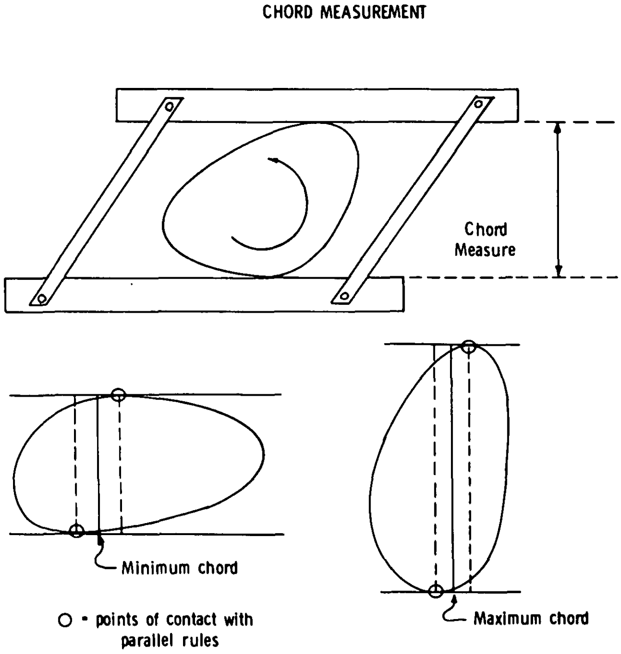

Fig. 1. Major and minor chord measurement. The digitization of each ring is rotated through 180° in a PL-1 computer program. At 5° intervals, the ring width is measured as the perpendicular distance between simulated parallel rules (Chord measure), and the maximum and minimum chord widths identified as the major and minor chords, respectively. Two line-segments are constructed perpendicular to the rules and intersecting at the points of contact of rules and ring (broken lines). Chord endpoints are located on the parallel rules midway between the constructed line-segments.

keratoconic groups of corneas. Such validation is necessary before the method can be employed to measure change in groups of corneas.

Materials and Methods

Subjects

Thirty eyes from twenty adult subjects were distributed to three astigmatism groups. A Symmetrical (S) group included six right and four left eyes in which keratometric horizontal and vertical readings were equal. In a Regular (R) astigmatic group containing five right and five left eyes, vertical exceeded horizontal keratometric readings by more than 0.5 diopters (range: 0.625D to 2.00D), and the vertical principal meridian ranged between 85° and 95°. Five right and five left eyes were included in a Keratoconic (K) group defined by a combination of criteria, including a cone on retinoscopy or over a red ophthalmoscope reflex, apical corneal thinning, central corneal subepithelial fibrosis and scarring, Fleischer's ring, Descemet's striae, and Munson's sign. Subjects' corneas were represented by keratographs produced by the Reynolds' corneascope.

Photogrammetric Index Method (PIM)

Keratographic patterns of the outer eight rings produced by the corneascope were enlarged and manually traced from Kale opaque projector images. The outermost eight rings were used and were numbered sequentially from in to out. Projector distortion was found to be 0.5 mm in 95 mm. Tracings were stream-digitized at 0.1-inch intervals on a Bendix Data Grid or 0.05-inch intervals on a Tektronix 4956 Digitizer.

PIM indices resulted from a PL-1 computer program. The digitization of each ring in a Cartesian coordinate system was rotated through 180° to 5° intervals as if between enclosing parallel rules. The width of the ring at each interval was measured as the shortest distance between the rules (Fig. 1). Chord end points were obtained that located the chord perpendicular to the parallel rules and midway between the ring points of contact with the parallel rules. Major and minor chords of each ring were defined as the chords equal to the maximum and minimum ring widths. Ring indices were developed that produced separate values for each ring of each keratograph. Diagrams of these indices are shown in Fig. 2. Eccentricity (E) is computed as the minor chord length divided by the major chord length, such that E of a circle would be 1, and of a severely elongated shape would be close to 0. Angularity (A) is the measure of the acute angle between major and minor chords, scaled such that A of a 90° intersection would be 1 and of an extremely acute angle would be close to 0. Major Symmetry (SM_o) is the shorter length divided by the longer length of the major chord segments created by intersection with the minor chord. If such chord segments were of equal length, SM_o would be 1. More disparate segment lengths would yield an SM_o closer to 0. Minor Symmetry (SM_a) is completely comparable to SM_o but relates segments of the minor chord.

In addition, two whole eye indices were developed that combine the chords from all rings of one keratograph. The values derived represent qualities of the entire corneal area enclosed by the keratograph. The first, Cluster (C), is comprised of two measures of consistency, each computed separately for major and minor chords (Fig. 3). Angle Cluster (C_A) is the standard deviation of the measures of the angles between each chord and a constant reference line; this reflects the consistency of the chord directions from central to peripheral cornea. Distance Cluster (C_D) describes the tendency of chords to pass through a common location. It assesses the proximity of chords to one another, not their proximity to either the optical or visual centers. The origin of the coordinate system for each keratograph is relocated to the mean of intersections between

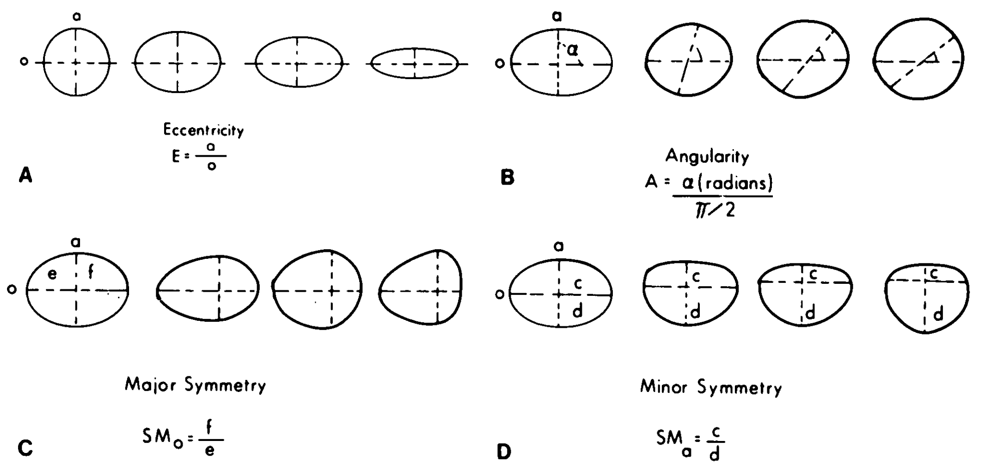

Fig. 2. Schematics of the ring indices. **A**, The eccentricity (E) index is the minor chord length (a) divided by the major chord length (o) of a keratographic ring such that E of a circle would be 1, and of a severely elongated shape would be close to 0. **B**, The angularity (A) index is the acute angle measure (α) between the major (o) and minor (a) chords of a keratographic ring scaled such that A of a 90° intersection would be 1 and of a much more acute angle would be close to 0. **C**, The major symmetry (SM_o) index is the shorter length (f) divided by the longer length (e) of the major chord segments (o) created by intersection with the minor chord (a) such that if chord segments were equal, SM_o would be 1. For more disparate segments, SM_o would be close to 0. **D**, The minor symmetry (SM_a) index is the shorter length (c) divided by the longer length (d) of the minor chord segments (a) created by intersection with the major chord (o). This results in a value analogous to SM_o.

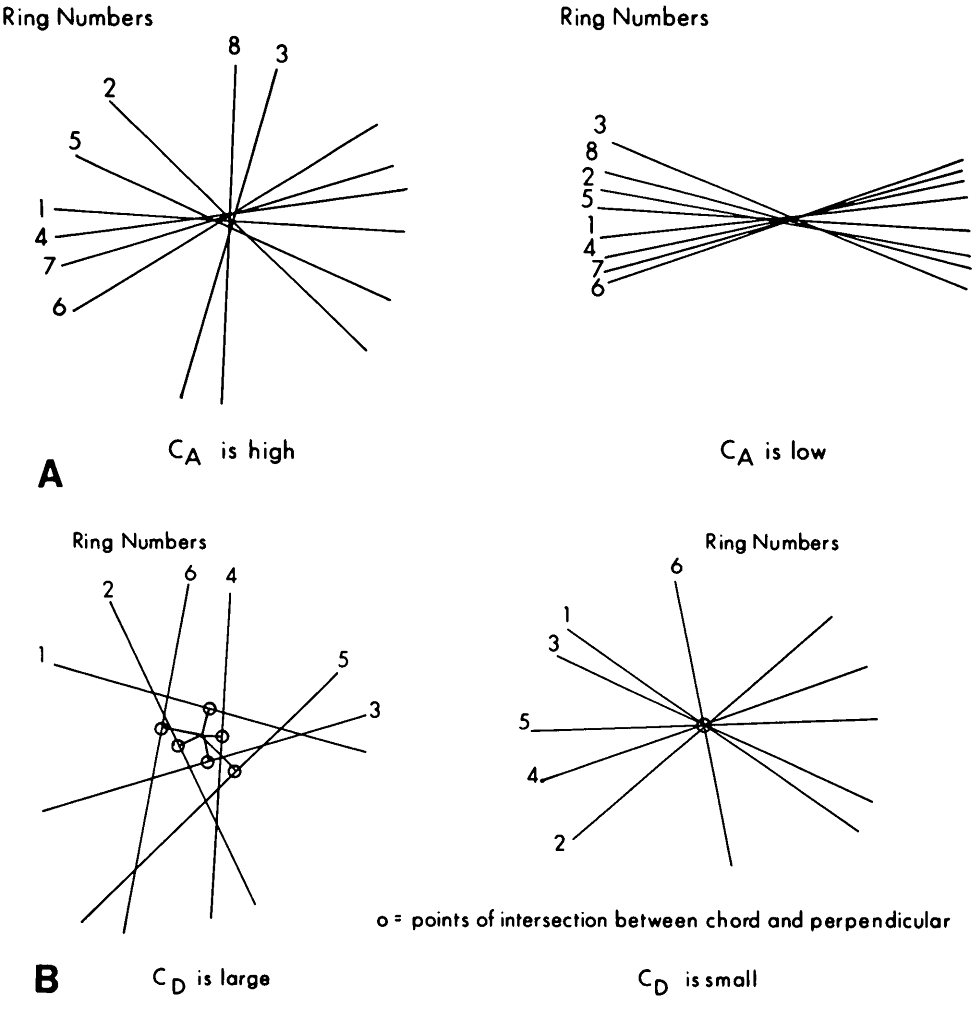

Fig. 3. Examples of the cluster (C) index. **A**, The angle cluster (C_A) index is the standard deviation of the measures of the angles between each chord and a constant reference line which reflects the consistencies of the chord angles from central to peripheral cornea. Major and Minor chords are processed separately. **B**, Distance cluster (C_D) describes the tendency of chords to pass through a common point. One point on each chord from each ring of one keratograph designates the closest approach of the chord to a central point. The index, C_D, is the standard deviation of the distribution of these points around the central point. Major and minor chords are processed separately.

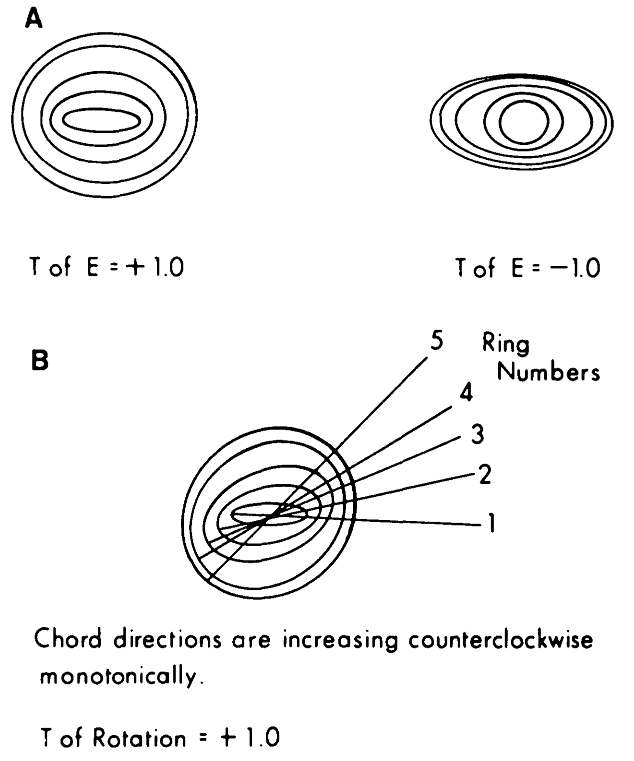

Fig. 4. Examples of the trend (T) index. **A,** If Eccentricity values increase towards the periphery, T of eccentricity approaches +1.0; if eccentricity values decrease towards the periphery, T of eccentricity approaches −1.0. **B,** A monotonic counterclockwise rotation of chords toward the periphery yields a T of rotation of +1.0. Clockwise rotation of chords toward the periphery would yield a T of rotation that would approach −1.0.

major and minor chords, and each chord is represented by the coordinates of its closest approach to this relocated origin. A point, the least squares mean, is located that minimizes the sum of the squared distances from this point to those coordinates. C_D is a standard deviation of the shortest distances from this point to each chord.

The second whole eye index, Trend (T), is the Spearman Rank correlation between ring numbers (1–8) and the values of each ring index. Each ring index is used to compute a separate T value for each cornea. An example of the T of one ring index, Eccentricity, is shown in Figure 4A. In addition, a T of Rotation index is defined as follows: The rotation orientations of the major chords for rings 2–8 are defined as their acute angles with the major chord for ring 1 measured between $\pm\pi/2$ radians. These angle values are then correlated with their ring numbers. A cornea whose major ring chords rotate counterclockwise monotonically from center to periphery would show a T of Major Rotation index value of +1.0 (Fig. 4B). Monotonic clockwise rotation would yield value of −1.0. Minor chords are also indexed for T of Rotation.

Predictions

Where possible, directional predictions describing expected differences among groups were formulated according to keratometric group definitions, the definition of irregular astigmatism, and anticipated enlarging and digitization error.[7] The corneal area measured by the keratometer is usually enclosed by the first two corneascopic rings used in our analysis. Thus, differences between S and R groups that were predicted on the basis of keratometry were evaluated by us in the larger area encompassed by the corneascopic rings. These predictions assumed that our major and minor chords would correspond to the principal meridians located by keratometry.

Predictions are listed in Table 1. If the rate of change in corneal curvature from center to periphery were the same in all meridians, this three-dimensional symmetry would produce corneascopic reflections that have circular rings regardless of the geometric nature of that rate of change. Thus, S-group corneas, which had no measurable keratometric axes, were expected to produce circular keratographic rings. Differing curvatures of their principal meridians defined the R group whose rings, therefore, were expected to be truly elliptical. K

Table 1. Sensitivity of PIM to discriminate among groups; symmetrical (S) versus regular (R) versus keratoconic (K)

	Prediction		
	Population		
Index	*Means*	*Std. Dev.*	*Result*
Eccentricity	S > R > K		supported ($P = 6.0 \times 10^{-7}$)
		S < R	supported ($P = 3.5 \times 10^{-2}$)
Angularity	S < R		supported ($P = 3.9 \times 10^{-3}$)
	K < R		not supported ($P = 3.6 \times 10^{-1}$)
		S > R	not supported ($P = 1.4 \times 10^{-1}$)
Symmetry, major	S > K < R		supported ($P = 2.6 \times 10^{-3}$)
		S < K > R	not supported ($P = 2.6 \times 10^{-1}$)
Symmetry, minor	S > K < R		supported ($P = 2.0 \times 10^{-2}$)
		S < K > R	not supported ($P = 8.1 \times 10^{-1}$)
Angle cluster, major		S > R	not supported ($P = 9.4 \times 10^{-2}$)
minor		S > R	supported ($P = 3.0 \times 10^{-2}$)
Distance cluster, major		K > S	supported ($P = 3.9 \times 10^{-2}$)
		K > R	not supported ($P = 1.1 \times 10^{-1}$)
minor		K > S	supported ($P = 2.2 \times 10^{-3}$)
		K > R	supported ($P = 6.5 \times 10^{-3}$)
Trend Eccentricity	no prediction		mean Spearman r for K group = 0.682 ($P = 1.0 \times 10^{-3}$)
Angularity	no prediction		mean Spearman r for K group = −0.289 ($P = 1.4 \times 10^{-2}$)

group rings were expected to reflect irregular astigmatism.[7] Specific predictions for indices relied on interpreting three-dimensional, physical, corneal shapes according to their two-dimensional keratographic images and anticipating the influence of ring shape on our indices.

We predicted that S group rings would show E values near 1.0 since their major and minor chords of their nearly circular rings would be approximately equal. Elliptical R group rings were expected to have lower mean E values than circular S group rings, but higher than distorted K group rings. We expected E values of the R group to be more variable than those of the S group because R keratometric readings reflected a range of astigmatism.

Since S group corneas theoretically have no principal meridians, major and minor chords would result only from manual digitization and/or tracing errors of their circular rings. Such error could be presumed random. In regular astigmatism, axes tend toward orthogonality and were between 85° and 95° by keratometry in our sample. Thus A mean ring values were predicted closer to orthogonal in the R than in the S group. Keratoconic corneas frequently display oblique, bi-oblique, or irregular astigmatism. Thus, R group A values were predicted higher than K group A values that would be the measures of irregularly oval rings. We expected the random nature of digitization errors to produce more variability of A in the S group than would be found in the R group.

SM mean values for the K group would reflect disparate chord segments because keratoconic irregular meridianal corneal curvatures conform to no geometric figure.[7] Therefore, these mean values were predicted to be lower on the average than SM mean values for the S and the R groups whose rings were expected to be symmetric. Due to inclusion of varying degrees of keratoconic severity in the K group, the degree of surface irregularity was expected to vary greatly. This dictated a prediction that SM values would be most variable in this group.

The whole eye index, C, examined consistency from the central through the peripheral cornea. Because we predicted that the relationship between the principal meridians established by keratometry in the S and R groups would continue unchanged toward the periphery, both S and R group corneas were predicted more likely to have chords that would share a common central point than chords representing irregularly asymmetric K group rings. Therefore, we predicted that mean C_D of K group would be higher than C_D of R and S groups. R corneas were expected to have lower C_A values than S corneas whose chord directions were expected to be random. No predictions were formulated for the T index.

Table 2. Statistical procedures used

Index	*Statistical procedures*
Ring indices	
Eccentricity Angularity Symmetry, major Symmetry, minor	1. Group means and standard deviations were found for each ring, each index. 2. Binomial distribution was used to test predicted directional differences among groups.
Whole eye indices	
Angle cluster, major Angle cluster, minor	1. Standard deviations of the chord angles were found for each keratograph.
Distance cluster, major Distance cluster, minor	2. Standard deviations of the chord distances were found for each keratograph. 3. ANOVA-based pairwise comparisons discriminated among groups.
Trend	1. Spearman Rank Correlations were found between ring number and index (or Rotation value) for each keratograph. 2. *P*-values for each group's difference from zero were found using the Wilcoxin Signed Rank test.

Data Analysis

Statistical methods used for each index are summarized in Table 2. Using the PIM, ring index values (E, A, SM_o, SM_a) were found for each ring of each digitized keratograph. For each of our eight ring positions in each group, means and standard deviations were computed. Across groups, differences among means and among standard deviations were evaluated against our directional predictions. For each prediction, a frequency of agreement was defined as the number of rings whose means or standard deviations showed directional differences in accordance with the prediction. Based on these observed frequencies, the approximate *P*-value for each prediction was calculated using the binomial distribution.

One-way analysis of variance was used to detect differences among groups for the C indices. Pairwise comparisons of means were carried out with Type I error rates controlled via the use of multiple comparison procedures. T index means for each group were tested by the Wilcoxin Signed Rank test for their differences from zero. *P* values are reported.

Results

Results are summarized in Table 1. Means of the E index confirmed the prediction that the S group would have the most circular rings followed by R group, and that K group would have the least circular rings

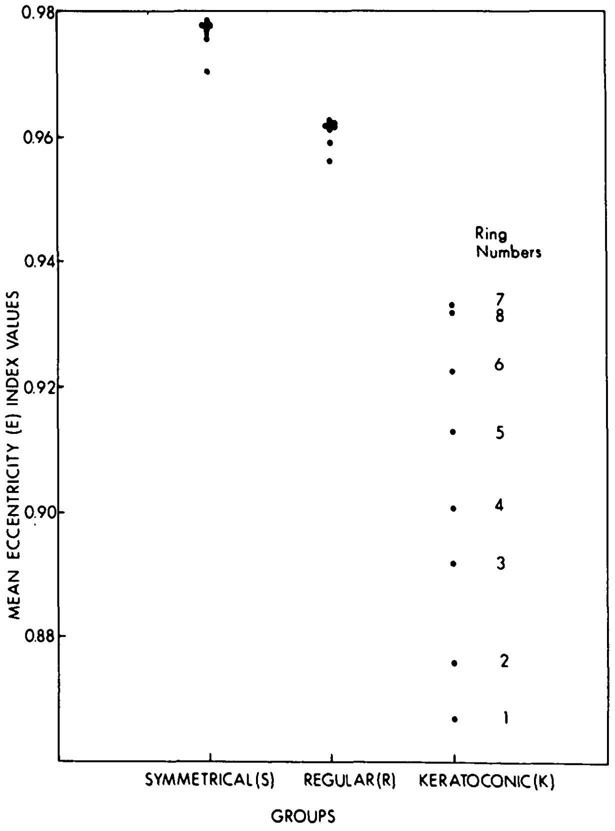

Fig. 5. Mean eccentricity (E) values for each ring by symmetric (S), regular (R), and keratoconic (K) groups.

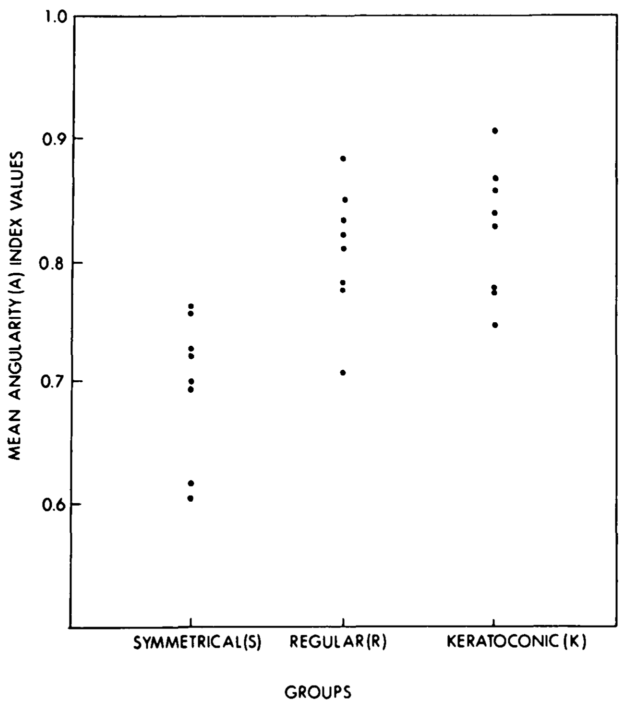

Fig. 6. Mean angularity (A) values for each ring by symmetrical (S), regular (R), and keratoconic (K) groups.

($P = 6.0 \times 10^{-7}$) (Fig. 5). The variability of E in S group was significantly less than that of R group ($P = 0.035$).

The mean ring values for A index showed that angles of intersection between chords were closer to 90° in R rings than in S rings ($P = 0.0039$). However, R rings showed intersection angles no more orthogonal than K rings, a repudiation of our prediction (Fig. 6). S angles of intersection were no more variable than R angles.

Keratoconic rings showed more distortion than S or R rings according to both Symmetry indices (SM_o: $P = 0.0026$; SM_a: $P = 0.02$) (Fig. 7). The greater variability of distortion expected in K-rings was not significantly greater than that of R or S rings.

Means and standard deviations of C_A and C_D values are shown in Table 3. C_A values showed that the directions of S group minor chords were more variable than R group minor chords ($P = 0.03$). For minor chords only, C_D was higher for K group than for S group ($P = 0.002$) and also higher than for R group ($P = 0.007$).

Although no predictions had been made for T indices, two T values were significantly different from zero. T of E showed a mean correlation of +0.68 for K group ($P = 0.01$). T of A showed a mean correlation of −0.29 for K group ($P = 0.02$).

Discussion

Any method that proposes a set of concepts based on new measurement techniques must be validated against well-established definitions and accepted units of measure. Testing our photogrammetric index values against expectations for predefined groups of corneas evaluates the accuracy of our quantification techniques, suggests what kinds of new information may be the unique products of our indices and provides the first step in establishing new norms for the evaluation of corneal surfaces.

The process of tracing and digitizing to locate major and minor chords was sufficiently sensitive to discriminate between symmetrical, regularly astigmatic, and keratoconic groups of corneas. As corneas departed from three-dimensional symmetry, our quantification reflected increased ellipticity of the keratographic rings. The E index yielded a small range of values close to 1.0 for the S group (Fig. 5). In R group, the amount of astigmatism documented by the keratometer was highly correlated with the mean E value for each cornea (r = −0.90). The rings of the keratoconic group were significantly the most eccentric (Fig. 5).

Our techniques to locate the major and minor chords in keratographs of regularly astigmatic corneas did detect predicted differences from three-dimensionally symmetrical corneas. R group chords did intersect closer to 90° than S group chords (Fig. 6). The most highly curved principal meridian (minor chord) had more consistency of direction in the R than in the S group (Table 1). The same effect, although not significant, was seen in the direction of difference between means in the lessor curved principal meridian (Table 3). Moreover, both the directions of the principal meridians and the ratios between their curvatures as detected in the central cornea by keratometry persisted throughout the annular regions measured by the corneascope since neither T of Rotation nor T of E were different from zero for R group.

Our measurements were also able to detect the asymmetry that is characteristic of keratoconic corneas. Major and minor SM indices showed K group values less than both S and R groups (Fig. 7). As anticipated, the irregular astigmatism of these keratoconic corneas produced keratographs with a variety of asymmetric rings. For the most highly curved principal meridian, the C_D index showed that K group chords measuring different annular regions were less likely to share a common center than either R or S group chords (Table 1). Although not significant for the lessor curved principal meridian, differences between means followed the same pattern (Table 3).

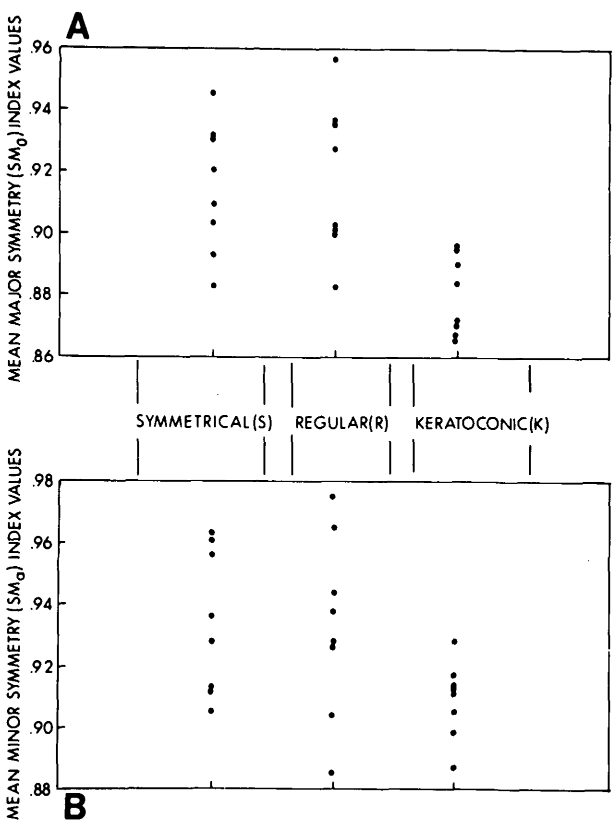

Fig. 7. Mean Symmetry values for each ring by symmetrical (S), regular (R), and keratoconic (K) groups. **A**, Major symmetry (SM_o). **B**, Minor symmetry (SM_a).

Table 3. Means and standard deviations of cluster index values

Index	Group: *Symmetrical (S)*	*Regular (R)*	*Keratoconic (K)*
Angle cluster (C_A)			
Angle cluster, major			
Mean	0.250	0.161	0.236
SD	0.125	0.127	0.160
Angle cluster, minor			
Mean	0.130	0.077	0.116
SD	0.045	0.019	0.067
Distance cluster (C_D)			
Distance cluster, major			
Mean	0.045	0.048	0.065
SD	0.011	0.023	0.029
Distance cluster, minor			
Mean	0.074	0.075	0.115
SD	0.018	0.023	0.039

Inaccuracy of the manual enlargements of keratographic rings and conversions of those images to sets of digital locations did interfere with the precise determination of our chords. If digitization error were random, A of S group corneas would have averaged 0.5 (halfway between 0° and 90°) and would have been more widely distributed than in R corneas. In fact, the mean A for S group was 0.70, reflecting systematic rather than random digitization error, and the standard deviation of A was not significantly larger in S than in R groups. Error-free translation of keratographs to digitized rings should have produced low variability of SM for S and R groups, discernible from SM of K group. However, there were no significant differences between the standard deviations of SM for S and R groups and for K group. It appears that the unevenness of manual translation introduced perturbations in S and R rings that altered the location of chords.

The PIM produced quantitative, photogrammetric information about corneal shape and astigmatism that cannot be statistically represented by other methods of corneal measurement such as keratometry and discrete point measurement. Our results showed that the circularity of K group rings increased progressively toward the periphery as evident in a significant, positive T of E correlation. This documents an increase in the three-dimensional symmetry of these keratoconic cor-

Table 4. Group norms for indices

Index	Group Symmetrical (S)	Regular (R)	Keratoconic (K)
Eccentricity			
Mean	0.976	0.961	0.904
SD	0.008	0.013	0.067
Angularity			
Mean	0.698	0.808	0.835
SD	0.208	0.163	0.150
Symmetry, major			
Mean	0.915	0.918	0.880
SD	0.074	0.064	0.083
Symmetry, minor			
Mean	0.937	0.933	0.902
SD	0.072	0.061	0.070
Trend of eccentricity			
Mean	0.139	0.048	0.682
Trend of angularity			
Mean	0.264	0.334	−0.289
Trend of symmetry, major			
Mean	0.095	−0.066	−0.020
Trend of symmetry, minor			
Mean	0.067	0.080	0.059
Trend of rotation, major			
Mean	0.144	−0.046	−0.185
Trend of rotation, minor			
Mean	−0.354	0.217	0.157

neas toward the periphery. A significant negative T of A correlation for K group is the result of the negative relationship between E and A. The correlation coefficients of E with A were −0.45 for S, −0.75 for R, and −0.64 for K. Because the more peripheral rings in K group keratographs are closer to circular, their A values are more affected by tracing and digitization error and therefore, less likely to be orthogonal.

On the average, the chords of K group rings formed intersections as close to 90° as those of regularly astigmatic rings, a phenomenon that was unmeasurable by keratometry because of distorted mires. However, unlike regularly astigmatic corneas, this group of keratoconic corneas had less clearly defined principal meridians from limbus to limbus. Our C_A index suggested that the directional orientation of chords varied more in K-corneas than in R corneas (Table 3). The surface irregularities of these keratoconic corneas appeared to produce roughly orthogonal principal meridians in annular corneal regions that varied greatly from center to periphery as indicated by a high C_A value in K group. Thus, these irregularly astigmatic corneas had oblique astigmatism.[7]

No significant differences between groups were found on T of Rotation for major or minor chords. However, one R group and four K group corneas had T of Rotation values (minor chords) higher than 0.84. Annular rotation of minor axes may constitute a subset of keratoconus that, perhaps, represent a disease stage or type. There was no relationship between minus or plus R values (clockwise or counterclockwise rotation respectively) and laterality.

Although such information about the astigmatism of keratoconic corneas may have been perceived by clinicians and investigators who have observed many cases of keratoconus, our method provides a formulation of these concepts. The extent of such phenomena can be quantified in different groups of corneas.

The usefulness of the PIM norms for our three corneal groups is limited by the breadth of the categories of corneas they represent. Preliminary norms for our indices are shown in Table 4. C values shown in Table 3 also constitute norms. PIM indices are descriptors of the ways in which corneas can depart from symmetry. Unlike methods that identify curvature at discrete points, PIM indices can quantify the magnitude and nature of corneal surface distortion. The information given by one index becomes more meaningful when taken in context with that of another index. Index values can be averaged to represent the distortion in any group of corneas and to evaluate changes in a group or an individual cornea over time. Future norms can be developed to define stages of disease, postsurgical recovery, or the effects of contact lenses, thereby influencing treatment techniques.

Key words: cornea, topography, astigmatism, keratoconus, corneascope

References

1. Gullstrand A: The cornea. *In* Helmholtz's Treatise on Physiological Optics, Vol. 1, Southall JPC, editor. Rochester, New York, Optical Society of America, Appendix II, 1924, pp. 301–334.
2. Bier N: A study of the cornea. Br J Physiol Opt 13:79, 1956.
3. Noto F: Studies on the form of anterior corneal surface. Acta Soc Ophthalmol Jpn 65:447, 1961.
4. Reynolds AE and Kratt HJ: The photo-electronic keratoscope. Contacto 3:53, 1959.
5. Hamilton CB: An investigation of corneal profiles. Contacto 7:9, 1963.
6. Rowsey JJ, Reynolds AE, and Brown R: Corneal topography: corneascope. Arch Ophthalmol 99:1093, 1981.
7. Duke-Elder S and Abrams D: System of ophthalmology, ophthalmic optics and refraction. *In* System of Ophthalmology, Vol. V. St. Louis, CV Mosby, 1970, pp. 274, 363.