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ORIGINAL ARTICLE

Contact Lens Base Curve Prediction from Videokeratography

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ABSTRACT: *Purpose.* To assess whether the contact lens to cornea-bearing relationship, as determined from the fluorescein pattern, can be predicted from videokeratography. *Methods.* Nineteen non-rigid gas permeable (RGP) lens wearers were each tested for fluorescein patterns with a series of seven RGP contact lenses of different base curves, and compared to a theoretical estimate of the fitting relationship from videokeratography. The experimentally determined alignment lens was then compared to the theoretical alignment (TA) value as determined from the central curvature and eccentricity. *Results.* The mean difference in lens choice between the TA and experimental alignment (EA) values was -0.01 ± 0.04 mm and between the simulated keratometric (KA) readings and the EA choice was 0.11 ± 0.05 mm. *Conclusion.* A knowledge of the eccentricity value from videokeratography allowed a better prediction of the base curve to cornea relationship than was provided by only a central corneal measurement. (Optom Vis Sci 1998;75:445–449)

Key Words: videokeratography, corneal topography, corneal eccentricity, contact lens

Contact lens fitting software programs have been incorporated into videokeratography units in recent years, either as part of the software package, or as an option.[1–7] With the computer-simulated fluorescein pattern for rigid gas permeable (RGP) lenses generated by the contact lens fitting program, manufacturers suggest that a practitioner's chair time can be decreased by reducing the number of trial fitting lenses.

The criteria for the selection of the base curve for a RGP contact lens vary widely, depending upon the goals and preferences of the fitter. The primary goal is to establish a physical relationship between the base curve and the cornea that allows lens positioning and movement within given limits. In addition, the choice of base curve also depends on other lens parameters, as well as the corneal shape. There is a physiological restraint in that the base curve selection must allow an exchange of some quantity of tears, and a physical restraint in that the lens cannot exert undue pressure on localized corneal areas, which can lead to cellular damage.

In most cases, when fitting a RGP contact lens using present techniques, an attempt is made to achieve a defined relationship between the base curve and the flattest meridian of the cornea. The base curve of the contact lens may equal or deviate slightly from the corneal curvature, depending upon other lens and corneal parameters. The primary lens parameters are the total diameter (TD) and optic zone diameter (OZD), whereas the primary corneal parameter is toricity. If the base curve is made equal to the flattest corneal curvature, as measured by the keratometer, the fitting relationship is known as "On K." Steeper or flatter fitting relationships are defined relative to the K value.

In fitting a contact lens On K, it is frequently assumed that there is a match in curvature between the base curve of the lens and the cornea when, in fact, this is only true for a spherical corneal shape. The actual corneal shape is sometimes described by an ellipse, in that there is a flattening of the curvature away from the center. The rate of corneal flattening may be expressed in terms of the usual mathematical expression for the flattening of the closest-fitting ellipse. In these terms, the average cornea has an eccentricity of about 0.5, with a range that is between about 0.3 and 0.7 for 95% of corneas.[8, 9]

The rate of corneal flattening affects the base curve to cornea fitting relationship. Because the base curve and cornea do not have the same shape, they cannot have perfect coincidence. As the corneal eccentricity is increased, the lens will make contact with only the corneal periphery, and there will be greater central clearance. However, the difference between the shape of the base curve and the cornea can be reduced by flattening the base curve. At some point this can result in a fitting relationship wherein the lens touches the cornea at three points, the center and each edge, with

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some clearance in between. This fitting relationship represents the most uniform fit that can be achieved between a spherical base curve and the elliptical corneal shape. In clinical terms, this physical arrangement of three-point touch represents the condition of best alignment. The difference in peripheral flattening among corneas with identical central radii of curvature suggests why, in order to achieve a given fluorescein pattern, one might require RGP lenses with back optic radii (base curve) that differs by as much as 0.2 mm (1.00 D) in extreme cases.

The purpose of this study is to assess whether the best alignment contact lens to cornea-bearing relationship can be predicted from corneal topography using the contact lens software program's videokeratography values for central corneal curvature and eccentricity. If the corneal eccentricity were known, it should be possible to predict what curvature was needed for the contact lens base curve that would achieve three-point touch. This can be verified clinically by using the fluorescein test.

METHODS

A calculation is made for the sagittal depth of the cornea over an area corresponding to that of the optical zone of the contact lens. The spherical curve that coincides with the center and edges of this area is then determined as the best fit contact lens.

The anterior corneal surface is described by the best fitting ellipse for each meridian.[10] Differences in the rate of peripheral corneal flattening are identified in terms of the eccentricity of an ellipse.[11]

Using the sagittal depth in equation 1 at a given diameter for a given elipse (the cornea)[1, 12]

$$s = \frac{r_{ap}}{1 - e^2} - \sqrt{\left(\frac{r_{ap}}{1 - e^2}\right)^2 - \frac{h^2}{1 - e^2}} \qquad (1)$$

where

e = eccentricity
r_{ap} = prolate apical radius
h = half diameter of a given ellipse

the radius of curvature of a spherical surface that would have the same sagittal depth at the same diameter can be calculated:

$$r_{eq} = \frac{s^2 + h^2}{2s} \qquad (2)$$

where

s = sagittal depth of the cornea
h = half the optic zone diameter of the contact lens
r_{eq} = radius of curvature for the equivalent sphere on a contact lens

This would be equivalent to fitting a contact lens with three-point touch (Fig. 1). Because the contact lens has a spherical curve and the cornea is aspheric, there can never be a perfect alignment fitting relationship. The closest agreement would be when the RGP lens just contacts the cornea at three points—centrally and peripherally on either side of the cornea in one meridian (three-point touch) (Fig. 2). The three-point touch is hence considered the theoretical alignment fit .

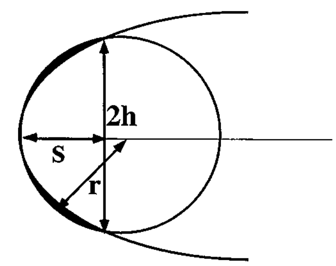

FIGURE 1.
Relationship of circle to ellipse with same sagittal depth.

Fig. 3 shows a graph that was constructed to find the radius of curvature for the equivalent sphere on a contact lens that will have three-point touch in a given cornea, based on equations 1 and 2.

From equation 1, it is found that the sagittal depth of the cornea decreases with lower eccentricity values when the radius of curvature was held constant (Fig. 4).

Subjects

Twenty-nine subjects (ages 23 to 28 years) were recruited from the School of Optometry, University of California at Berkeley, who satisfied the following criteria before admission into the study: (1) non-rigid gas permeable (RGP) lens wearer; (2) less than 1.00 D of corneal toricity; and (3) free of any corneal diseases.

Informed consent was obtained after a full description of the procedures. This study observed the tenets of the Declaration of Helsinki and was approved by the University of California, Berkeley, Committee for Protection of Human Subjects.

Corneal topography was measured using the videokeratograph and based on the selection criteria.

Up to three visits were required for each subject, including one preliminary examination and one or two contact lens fitting sessions, depending on the time limit. The average of 5 simulated keratometry readings and the eccentricity values measured from the videokeratograph were used to determine the theoretical alignment (TA) RGP lens (in terms of back optic radius, millimeters) in terms of the radius of curvature for the equivalent sphere on a contact lens (equation 2). It was assumed that the eccentricity value measured by the videokeratograph was correct.

The first experiment involved 19 subjects. A series of 11 RGP

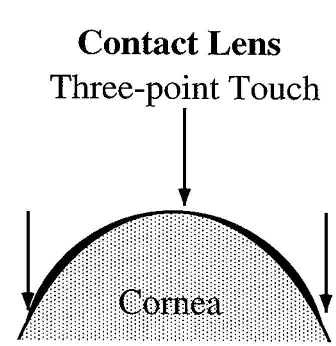

FIGURE 2.
Theoretical alignment fit occurs when the lens touches the cornea at three points: the center and each edge, with some clearance in between.

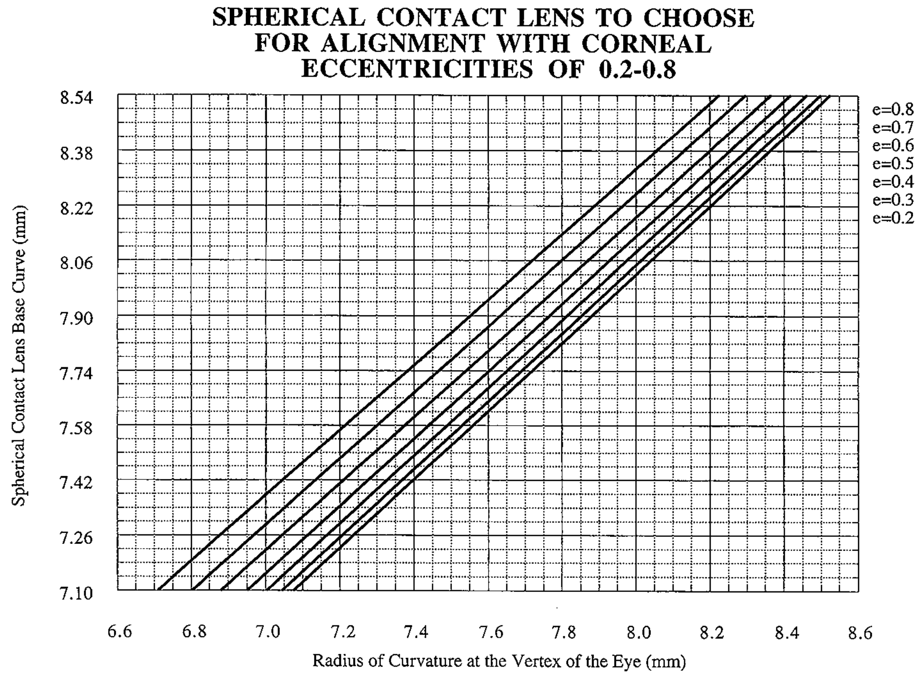

FIGURE 3.
Graph used to find the radius of curvature for the equivalent sphere on a contact lens that will achieve three-point touch on a given cornea.

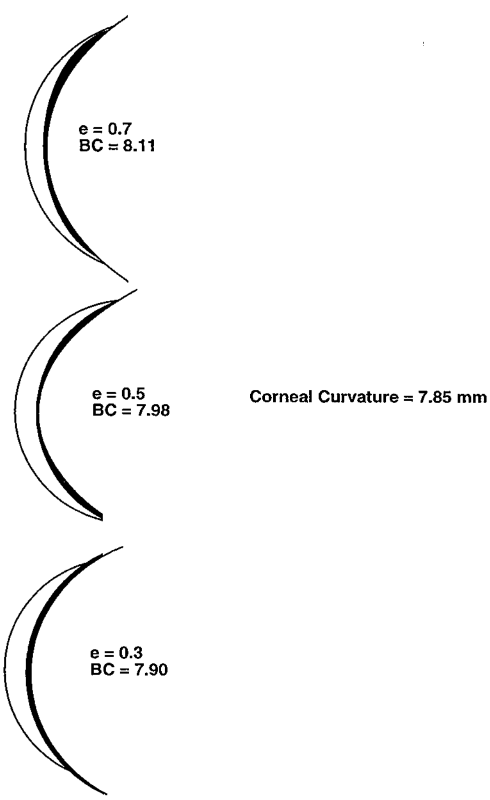

FIGURE 4.
The sagittal depth of the cornea changes with eccentricity values when the radius of curvature is held constant.

lenses were tested on each subject's right eye at the contact lens fitting sessions. The lenses were of bi-curve design (TD = 9.0 mm, OZD = 8.0 mm, light blend). Of the 11 lenses, 7 had different base curves (back optic radii), including the calculated TA lens, and lenses that were 0.75, 0.5, and 0.25 D steeper and flatter than the TA lens.

The first three lenses were presented for practice purposes to familiarize the investigator (JSC) with the characteristics of the fluorescein pattern for each subject. These three lenses were chosen of the seven study lenses described previously. After the first three lenses were presented, they were returned to the study lens set. One of the seven study lenses was chosen as a repeat lens. The seven study lenses and the repeat lens (total of eight) were then masked and given to the investigator in a random order by the assistant.

The contact lens to cornea relationship was determined experimentally using the fluorescein test. A RGP contact lens was first placed onto the eye and allowed to settle for about 1 to 2 min. The observed lens fit was judged as being steep, on alignment (experimental alignment), or flat, and then quantified in diopters (D).

A second experiment was performed in which the same procedure was repeated by two other investigators (CR and LJ), using the same masking and randomized presentation as for investigator JSC. However, no practice session was allowed before the lens assessment and no repeat lens was used. Nine non-RGP wearers were each fitted with five RGP contact lenses based on the theoretical estimate of the fitting relationship. The five lenses were the theoretical alignment lens, 0.25, 0.50 D steeper and flatter lenses.

RESULTS

Fig. 5 represents the relationship between the base curve radius for the TA lens and the experimental alignment (EA) lens for the 19 subjects of experiment 1. A high association was found between the two methods of lens choice (r = 0.98). Seven of 19 lenses showed no difference between EA and TA lenses; 11 were within 0.25 D difference, and 1 was within 0.50 D difference. Of the 11 lenses, 6 lenses were steeper than the (TA) lens. Nearly the same

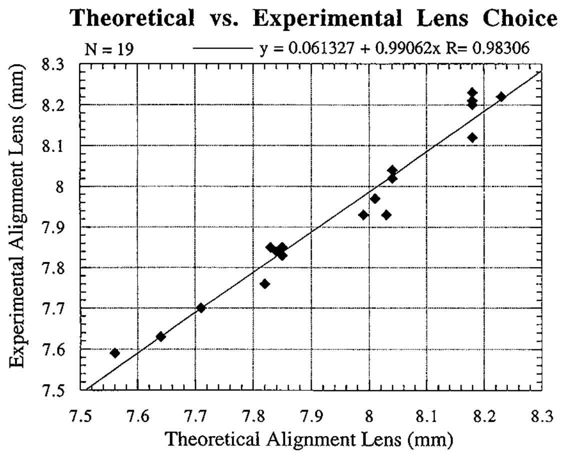

FIGURE 5.
Relationship between the base curve for the TA and EA lens choice in experiment 1 when a practice session was included.

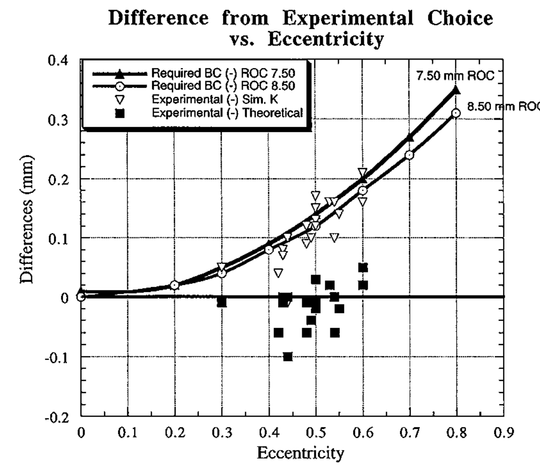

FIGURE 7.
Graph of experimental minus theoretical base curve for alignment. Data are re-calculated using central measurement only as simulated KA values and plotted as experimental minus simulated KA values. The curves 7.50 mm ROC and 8.50 ROC represent the expected difference between the TA lens choice (with eccentricity) and the KA lens choice (without eccentricity) for radius of curvature of 7.50 and 8.50 mm.

results were found for the nine subjects who did not undergo a practice session before the experiment (Fig. 6).

Lens choice and eccentricity

The difference between the EA value and the TA value (EA−TA) was plotted relative to eccentricity; EA minus simulated keratometric readings (KA) were plotted also against eccentricity (Fig. 7). The mean was −0.01 ± 0.04 mm (range: −0.10 to 0.05 mm) and 0.11 ± 0.05 mm (range: −0.01 to 0.21 mm), respectively. Most values were within 0.50 D of the line $y = 0$, which represented no difference between EA and TA lens choices for all eccentricity values. A larger difference was found for (EA−KA) when eccentricity was not taken into account.

Fluorescein pattern assessment

When evaluating the ability of the investigator to assess fluorescein fitting patterns, the theoretical contact lens to cornea fitting relationship for each lens was compared to the experimental observation of the same relationship for the last 8 of the 11 lenses placed onto each subject's eyes. The distribution of this comparison is shown in Fig. 8.

The mean difference of the theoretical and observed assessment was 0.029 D, with a SD of 0.384 D. Sixty-seven percent of the observations were within 0.38 D; 95% of the observations were within 0.76 D.

In assessing the reliability of experimental observations by the investigator, the assessments for the repeated lens were compared for each of the 19 subjects. The absolute mean difference in assessment was 0.40 D (range: −1.25 to 1.25 D) and the mean difference was 0.03 D. The greatest difference in evaluation was 1.25 D. Fifteen of 19 lenses were within 0.50 D difference for the repeated lens, and 14 of the 19 subjects were within 0.25 D difference.

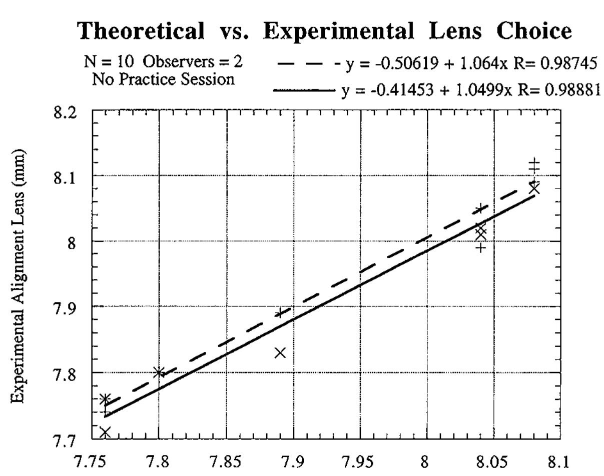

FIGURE 6.
Relationship between the base curve for the TA and EA lens choice in experiment 2 when there was no practice session before the lens evaluation.

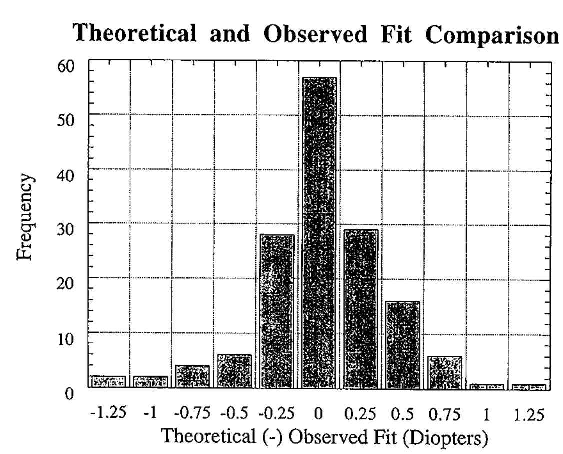

FIGURE 8.
A distribution of the difference in lens choice for 19 subjects in experiment 1 is shown.

Repeatability of eccentricity measurements

The repeatability of 5 eccentricity measurements on each of the 19 subjects was found to have a range for the SDs from 0.010 to 0.046 (Fig. 9).

DISCUSSION

We found a close relationship between the predicted (TA) alignment of a contact lens base curve with the EA, as determined by evaluating fluorescein patterns for a series of trial lenses with various base curves. The predicted alignment is based on a measurement of the central curvature and eccentricity of the test cornea using a videokeratograph. When only the central curvature (keratometer equivalent) was used to predict the theoretical base curve for alignment, it was found that there were greater differences from the experimentally determined alignment. In general, the lenses fitted too tight, indicating that the base curve was steeper than the cornea. This result is significant because practitioners often find that a contact lens base curve that is based on the KA value might appear to be on alignment for one cornea, and slightly flat or steep for other corneas. Based on our results, the contact lens base curve selection process could be improved by allowing for the effect of corneal eccentricity.

The repeatability of the experimental observation was evaluated when one of the seven lenses was presented twice to the investigator. Fourteen of the 19 lenses were within 0.25 D difference for the repeat lens. The greatest difference in assessment was 1.25 D. There was a suggestion that the difference in assessment was greater when the repeat lens was flatter than the TA fitting relationship. The order in which the lenses were presented was not investigated because of the complexity in multiple comparisons and the limited number of subjects used. This difference, however, also depended on the corneal toricity, the eccentricity of the corneas, and the clinical experience of the observer. Upon further evaluation, there was no obvious trend in the fluorescein assessment from the first to the second assessments for both the amount of corneal toricity and the eccentricity values. If the presentation order of the repeat lens was investigated, it might suggest an association between this and the difference in experimental observation.

The repeatability of the eccentricity measurement for the 19 subjects was consistent over the range of eccentricity values 0.41 to 0.60. The SD range of 0.01 to 0.04 was quite minimal. This finding was crucial because eccentricity can be used to predict the contact lens to cornea relationship. This would in turn help practitioners in selecting the most appropriate lens for any particular corneal shape.

In summary, a knowledge of the eccentricity value from videokeratography allowed a better prediction of the base curve to cornea alignment relationship than was provided by only a central corneal measurement.

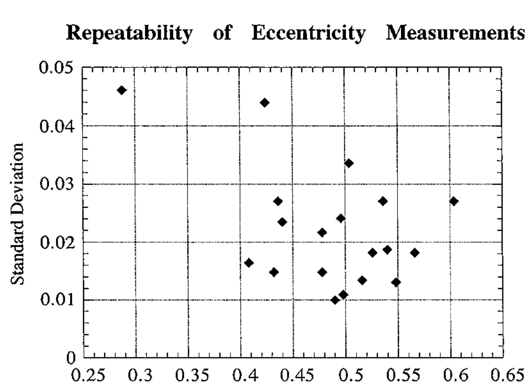

FIGURE 9.
The mean vs. SD of the 5 eccentricity measurements for each of the 19 subjects is shown.

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