THE EFFECT OF Z-VALUES

ON THE FIT OF RIGID CONTACT LENSES

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ABSTRACT

The purpose of this project is to determine the effect of z-values on the fit of rigid contact lenses on corneas with various degrees of eccentricity (different e-values) and make a statistical, graphical, written and video representation of the results.

The method of study included: 1) designing a trial lens set with 27 lenses using three different z-values (0.06, 0.10, 0.14) and nine different base curves/z-value (7.40-8.20 in 0.10 mm steps)(constants = OAD 9.2 mm, OZD 7.8 mm, power -3.0 OD). 2) Taking autokeratometer readings of corneal toricity and eccentricity (shape factor or e-values) on 30 patients. 3) Videotaping and evaluating the fit of each z-value on each cornea with the lens of appropriate base curve, paying particular attention to flourescein patterns, centration of lens and lens movement.

INTRODUCTION

Throughout the contact lens community, there has been a continuous effort to develop a lens with the ultimate properties in durability, histocompatibility, corneal fit and optics, which could function as the panacea of all contact lenses. Reaching this goal in entirity has not been possible to this date, but every year new advances put researchers that much closer. It is the goal of this study to address one aspect of rigid gas permeable lens design, which in the past has only gained a minimal amount of attention, edge lift and corneal topography relationships. This paper discusses a pilot study which was designed to observe the relationships between axial edge lift, corneal eccentricity values, and the affect these factors may have on the overall fit of rigid gas permeable contact lenses.

To familiarize the reader more with this topic, a brief discussion of a few principles involved is in order. Let us first address corneal topography. In general, it is accepted that the radius of curvature of the cornea is spherical and that this radius of curvature changes as it moves from the apex towards the periphery. The degree to which this change occurs can be measured and described using various methods. For simiplicity sake, only the terms used in this project will be discussed, shape factor (p) and eccentricity value (e-valve). These two terms are related exponentially and essentially represent the same principle - the level of corneal asphericity, i.e., the departure of the actual curve from the apical radius (Guillon, et al; 1986). In this project, a Humphries autokeratometer was used to measure shape factor. By using this relationship, $p = e^2$, eccentricity values were calculated. The e-value, corresponds to corneal asphericity in this manner (Figure 1) (Koetting, et al; 1989):

$e = 0$	circle
$e < 1$	ellipse
$e = 1$	parabola
$e > 1$	hyperbola

In general, most corneas flatten toward the periphery but the amount of asphericity can vary greatly between individuals.

Next, lets turn our attention to axial edge lift (z-values). Axial edge lift represents the depth of clearance between the edge of the lens and the cornea (Handal, et al; 1988). It is the distance between the posterior aspect of the lens edge to the extension of the back central optical radius, parallel to the axis of symmetry (Figure 2) (Koetting, et al, 1989).

Through various peripheral curve designs, various values for axial edge lift can be obtained. According to Bibby (Bennett, et al; 1985) there are three primary functions to peripheral curve design:

1. To prevent the edge of the lens from digging into the corneal surface during lens movement.
2. To permit circulation of tears beneath the lens in order to maintain corneal metabolism.
3. To support a meniscus at the edge of the lens to provide forces that cause the lens to center.

All three of these functions were considered when designing this project and are the essentials of a healthy fitting rigid gas permeable contact lens. It is the purpose of this project to study the effect of axial edge lift on the overall fit of rigid gas permeable lenses on corneas with various eccentricity values.

METHODS

Using Gerald Lowther's computer program for contact lens design, a trial lens set consisting of twenty-seven lenses was developed. Paragon Optical provided these lenses in their Paraperm II material. The set consists of nine different base curve values ranging from 7.40 to 8.20, in 0.10 mm steps. Overall diameter (OAD), optical zone diameter (OZD) and dioptric power were all held at these constant values, 9.20 mm, 7.80 mm and -3.00 D, respectively, Center thickness for all lenses was 0.16 mm. Peripheral curve design consisted of a secondary curve and a tertiary curve or bevel. The radii of these curves varied so each base curve was represented by each of these three z-values, 0.06, 0.10 and 0.14, going from steepest to flattest, respectively (Table 1).

Humphrey autokeratometer readings were taken for each patient volunteer. Included in these readings were measures of corneal shape factor, corneal toricity and location of the corneal apex. A trial lens was then chosen on the basis of the flattest corneal meridian. The base curve closest to that of the flattest meridian was chosen for each subject.

It was intended to complete this project with thirty subjects. Due to technical difficulties and time limitations, only fourteen subjects completed the project. Of these fourteen subjects, the mean age was 26.5

years with a range of 22 years to 60 years. Nine subjects were men and five were women. Four patients were previous rigid contact lens wearers. Two wore soft lenses. Eight had never worn contact lenses before. Seven left eyes were used and seven right eyes were used.

Each patient tried on three lenses, one of each z-value, 0.06, 0.101, 0.140. A drop of Proparacaine was instilled before each lens was inserted to minimize effects of lid sensation and tearing. A new fluorescein strip was also used with each new lens. These lenses were then filmed on the eye with and without the eyelids as a factor. Fluorescein patterns, lens movement and lens centration were then analyzed.

The first step in analyzing the data was calibrating the video screen used to account for magnification effects. The film was tnen played back frame by frame. Measurements of lens centration, movement and peripheral fluorescein patterns with and without eyelids in play were taken directly off the video screen. Ten measurements were taken of each parameter discussed. Each measurement was taken after a complete blink. These values were averaged for each parameter. A discussion of the results follows.

DISCUSSION

Discussed first are the results from the Humphrey autokeratometer readings of the fourteen eyes involved in this project. Eleven corneas exhibited with-the-rule corneal toricity averaging 1.10 D with a range of 0.25 to 3.0 D. Two corneas were against-the-rule with values of 0.25 and 0.37 D. One cornea was obliquely astigmatic with a value of 0.38 D. The average shape factor was 0.14, ranging from -0.06 to 0.30. The average eccentricity value was 0.340 with a range of 0.00 to 0.548. There were eleven ellipses, two circles, and one elliptical cornea very close to circular (e = 0.10).

Corneal eccentricity values were plotted against peripheral fluorescein pooling (mm) for each z value (0.141, 0.101, 0.06). For an axial edge lift of 0.141 (Figure 3) eight lenses showed pooling of 0.50mm. Three had minimum acceptable peripheral pooling of 0.25 mm and three showed uneven and excessive pooling. Two of the three corneas showing excessive pooling had e-values of zero. The other had an e-value of 0.30. Two of the three corneas with minimal pooling (0.25) mm) had e-values of 0.548 and 0.539. The third had an e-value of 0.374. The results of Figure 2 suggest that for an axial edge lift of 0.141, the majority of corneas will have adequate peripheral clearance. The more circular corneas may tend to have excessive clearance and the more aspheric corneas may not have enough.

The peripheral fluorescein patterns shown with lenses of z-value 0.101 were much more variable than those with z = 0.141 (Figure 4). There was a general decrease in pooling overall. Only one cornea (e = 0.00) showed excessive pooling. Three stayed at 0.50 mm. The remaining showed a decrease; two had 0.32 mm and six had 0.25 mm. Two corneas showed unacceptable amounts of peripheral pooling, 0.12 mm for an e-value of 0.539 and no pooling for an e-value of 0.548. This data shows a more variable response than that of z = 0.141. All the lenses still showed acceptable amounts of peripheral clearance except those on corneas with e = 0.539 and e = 0.548, the two most aspheric.

With an axial edge lift of 0.06 mm, peripheral pooling showed an even larger decrease (Figure 5). One lens still showed excessive and uneven pooling (corneal e = 0.00). Four had 0.25 mm of pooling which was still acceptable. Five lenses had unacceptable values of 0.14 mm to 0.12 mm, and four showed no peripheral pooling at all. The four corneas with no pooling had e-values of 0.00, 0.49, 0.539 and 0.548. Of the fourteen eyes used, only four showed even minimal acceptable levels of peripheral pooling. Those with no pooling seemed to be on either end of the extreme of corneal asphericity.

Comparing the behavior of peripheral fluorescein pooling with the three z-values used and also with corneal eccentricity values, a few general observations can be made. The lenses with z = 0.141 showed the most adequate and stable patterns. As the peripheral clearance decreased, in general, so did pooling levels. While, on the whole, and edge lift of 0.101 showed acceptable (not optimal) peripheral clearance, the majority of lenses with a z-value of 0.06 did not. Although the corneas with moderate eccentricity values behaved rather similarly, those at either end of the spectrum tended to show some differences. The corneas with higher degrees of asphericity tended to exhibit lower levels of peripheral clearance. Corneas with no or little asphericity tended to show excessive, uneven, and often unpredictable pooling patterns.

Evaluating centration and movement of these lenses was more difficult than observing peripheral fluorescein patterns. Based upon the average of multiple measurements of lens movement and centration, a "best" lens was chosen for each cornea (Figure 6). The lens with 0.50 to 1.00 mm of movement and closest to the center of the pupil was chosen. These measurements were taken with the eyelids in play. Of fourteen corneas, six were fit best with lenses of z = 0.141, six with z = 0.101 and two with z = 0.06. The results of this comparison were variable and no correlation between axial edge lift, corneal eccentricity and overall lens fit could be made.

Taking the last comparison one step further, a "best" lens was chosen based on centration movement and peripheral fluorescein patterns (Figure 7). Eight of the corneas preferred z = 0.141 lenses. Five were fit best with lenses of z = 0.101. Only one ocrnea was fit best with a lens of z = 0.06. One consistent observation can be made from this data. The four corneas with the highest e-values (0.490 to 0.548) were all fit best with lenses z = 0.141. There were no further consistencies apparant.

Considering sources and causes of the variability in lens behavior on corneas with similar shape values, the role of the eyelids comes to mind. Fluorescein patterns and lens centration were studied with and without the lids in play to address this issue. There were only minimal changes in peripheral fluorescein pooling when lids were removed. There were, however, significant changes in lens centration when the eyelids were removed for eleven of the fourteen eyes. It seems evident that the eyelids play a rather significant role in lens centration and movement. This accounts for much of the variability observed in this study.

CONCLUSION

Due to the limited number of subjects observed in this project, it is not practical to draw any formal conclusions based on statistical analyses. However, several significant observations regarding axial edge lift and corneal eccentricity values were made through the course of the study. It is these ideas that contact lens practitioners should keep in mind when fitting rigid gas permeable lenses. In general, it is apparent that a lens with a z = 0.141 is more likely to be a successful fit than a lens with all the same parameters, but less peripheral clearance. Peripheral fluorescein patterns showed a general trend in reduction as z-values decreased. For the cornea with a moderate eccentricity value, an edge lift of 0.10 would probably be adequate, but not necessarily optimal. Edge lift of 0.06 does not allow adequate tear exchange and peripheral clearance for most corneas. A few statements can be made in regard to corneal eccentricity.

Corneas with higher eccentricity values do not tolerate lenses with less peripheral clearance. These corneas may even require lenses with z-values greater than 0.141. They tend not to achieve adequate peripheral pooling with lenses of z = 0.101 and below. On the other end of the spectrum are corneas with very low eccentricity values (circular or close to it). These lenses show a variety of responses to the same and to different values of axial edge lift. Often with a z = 0.141 there will be excessive and uneven pooling. This trend seems to be less evident with moderate edge lift values. It seems, however, that lenses on these eyes are particularly vulnerable to the effects of eyelid forces. Lens behavior on these eyes tends to be very unpredictable.

While axial edge lift tended to have an overall predictable effect on peripheral fluorescein pooling, its role in lens centration and movement tended to be less consistent. No overall correlation between edge lift, corneal shape, and lens movement and centration could be made. It seems that lid forces play an equivalent or even greater role in lens movement and centration than axial edge lift. The majority of the eyes (57%) preferred a z-value of 0.141. There was no relationship between e-value and z-value observable here. It seems that lens centration and movement depend upon a combination of axial edge lift, corneal shape and lid forces. They can not be predicted by considering edge lift solely and must be done on a more individual basis.

In summary, axial edge lift and corneal shape appear to play an often predictable role in peripheral clearance and tear exchange in rigid gas permeable lenses. When considering lens movement and centration, axial edge lift and corneal topography tend to take a back seat to the influence of lid forces. It is the role of the contact lens practitioner to analyze these factors individually for each patient in order to do him/her justice with the optimal corneal-lens relationship.

SOURCES OF ERROR/AREAS OF IMPROVEMENT

In reviewing both the methods used and the results obtained in this project, there are evident sources of error and areas which would, in the future, benefit from some improvement. The sources of error include:

1. Inaccuracies and inconsistences in measurement of lens movement, centration and peripheral fluorescein patterns.
2. Variability and inconsistencies of Humphries autokeratometer.
3. Variability and inconsistencies in lid forces between patients.
4. Slight differences in magnification levels between patients and between different filming sessions.

Areas benefiting from improvement (not mentioned above) include:

1. Discriminating and classifying data on basis of lid coverage.
2. Increasing number of subjects for statistical analyses.
3. Incorporate a long-term wear element to evaluate cornea for physiological stress (for example, 3-9 staining, edema, mechanical stress, etc.).
4. Expanding base curve parameters of trial lens set to incorporate more extreme corneal shapes, both flatter and steeper.

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TABLE 1

Base Curve	2* Curve	3* Curve	3* Curve Width	OAD	OZD	Power	Z-Value
7.40	8.30	10.00	0.200	9.2	7.8	-3.00	0.103
7.50	8.50	10.00	0.200	9.2	7.8	-3.00	0.102
7.60	8.70	10.00	0.200	9.2	7.8	-3.00	0.101
7.70	8.90	10.00	0.200	9.2	7.8	-3.00	0.100
7.80	9.10	10.00	0.200	9.2	7.8	-3.00	0.099
7.90	9.40	10.00	0.200	9.2	7.8	-3.00	0.101
8.00	9.30	11.00	0.200	9.2	7.8	-3.00	0.101
8.10	9.50	11.00	0.200	9.2	7.8	-3.00	0.100
8.20	9.80	11.00	0.200	9.2	7.8	-3.00	0.101
7.40	7.80	9.00	0.200	9.2	7.8	-3.00	0.062
7.50	8.00	9.00	0.200	9.2	7.8	-3.00	0.063
7.60	8.10	9.00	0.200	9.2	7.8	-3.00	0.059
7.70	8.30	9.00	0.200	9.2	7.8	-3.00	0.060
7.80	8.50	9.00	0.200	9.2	7.8	-3.00	0.060
7.90	8.40	10.00	0.200	9.2	7.8	-3.00	0.062
8.00	8.50	10.00	0.200	9.2	7.8	-3.00	0.059
8.10	8.70	10.00	0.200	9.2	7.8	-3.00	0.060
8.20	8.90	10.00	0.200	9.2	7.8	-3.00	0.060
7.40	8.90	11.00	0.200	9.2	7.8	-3.00	0.139
7.50	9.20	11.00	0.200	9.2	7.8	-3.00	0.140
7.60	9.50	11.00	0.200	9.2	7.8	-3.00	0.141
7.70	9.80	11.00	0.200	9.2	7.8	-3.00	0.141
7.80	9.80	12.00	0.200	9.2	7.8	-3.00	0.141
7.90	10.10	12.00	0.200	9.2	7.8	-3.00	0.141
8.00	10.40	12.00	0.200	9.2	7.8	-3.00	0.141
8.10	10.70	12.00	0.200	9.2	7.8	-3.00	0.141
8.20	11.00	12.00	0.200	9.2	7.8	-3.00	0.140

*Center thickness of all lenses, 0.16 mm.

FIGURE 1

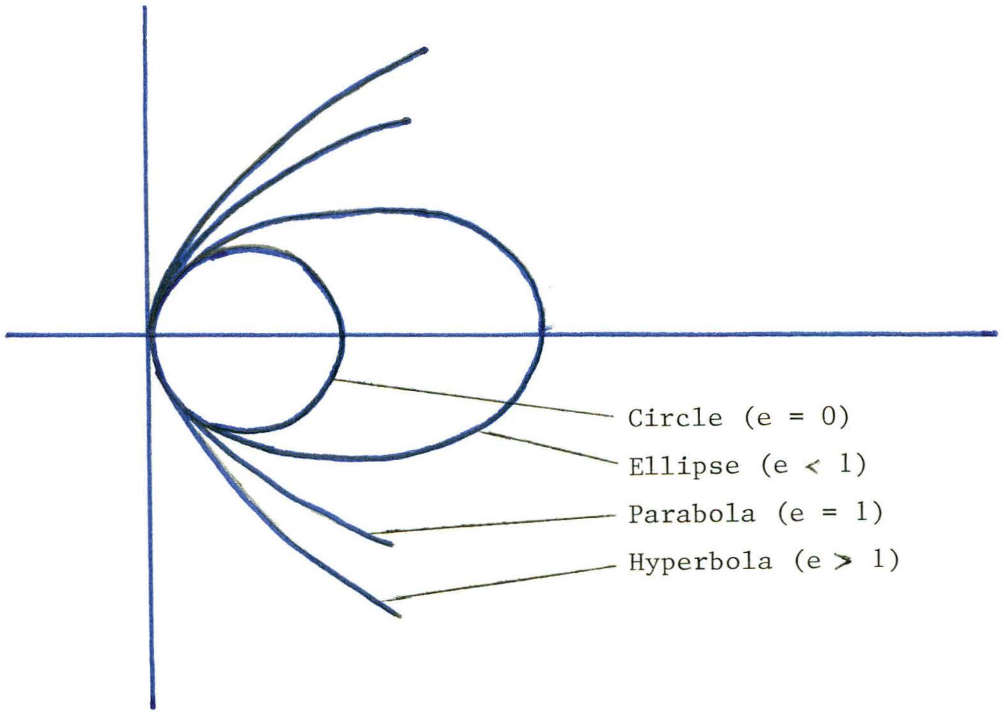


FIGURE 2

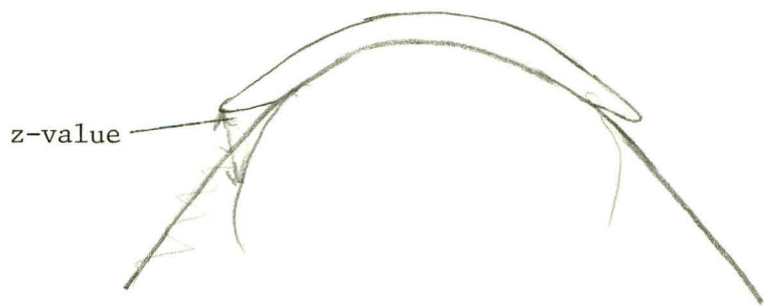


FIGURE 3

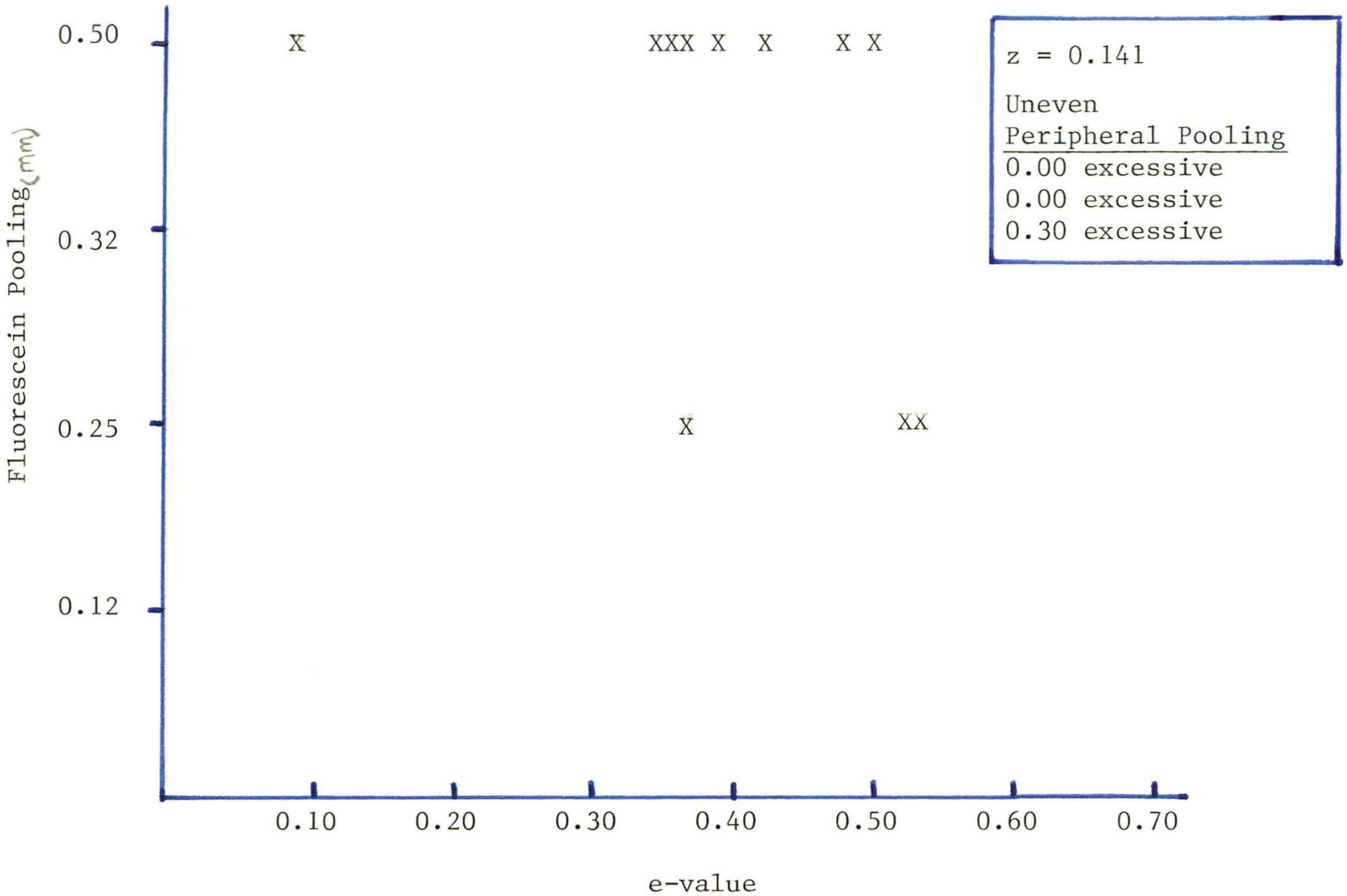
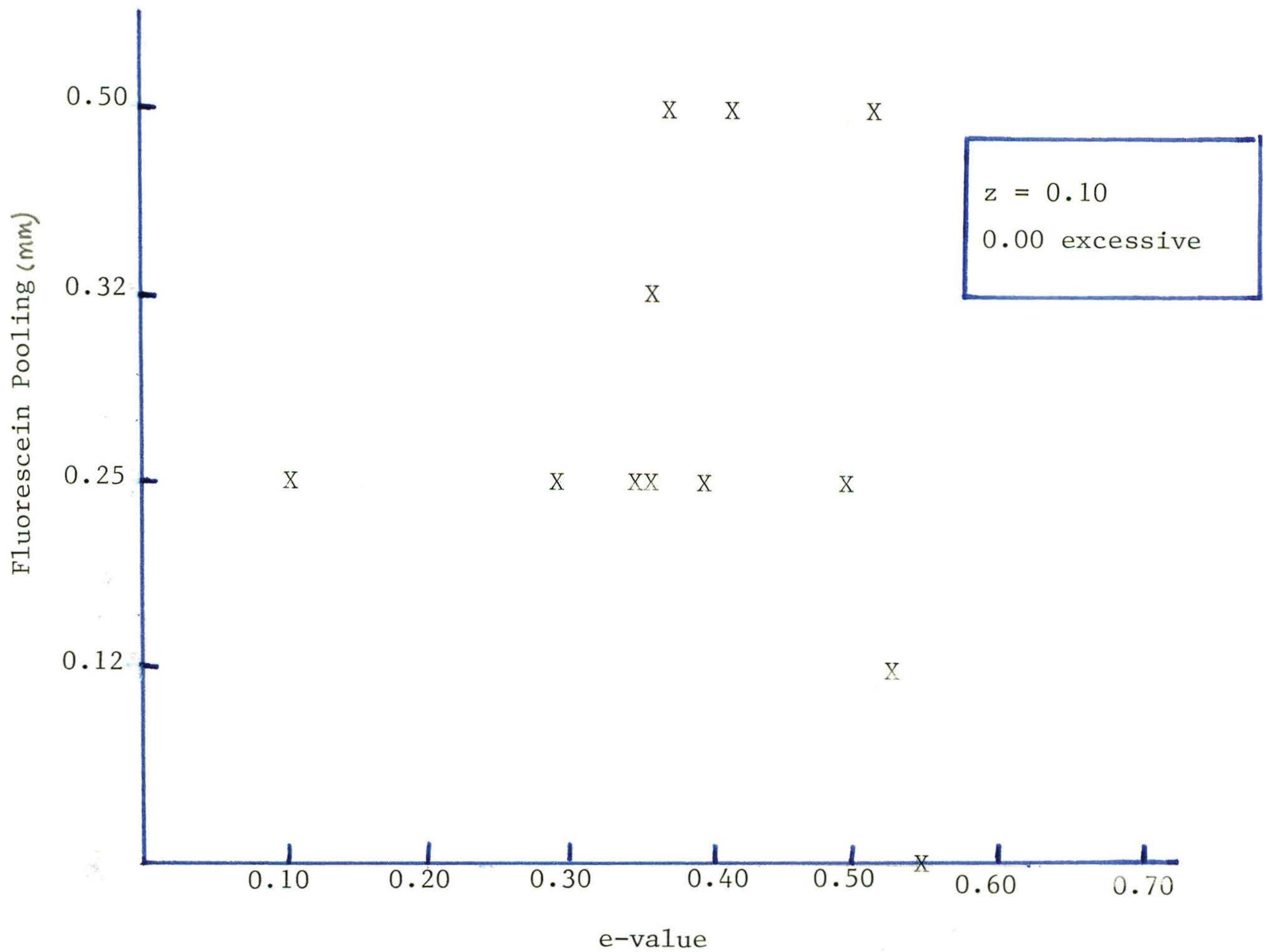
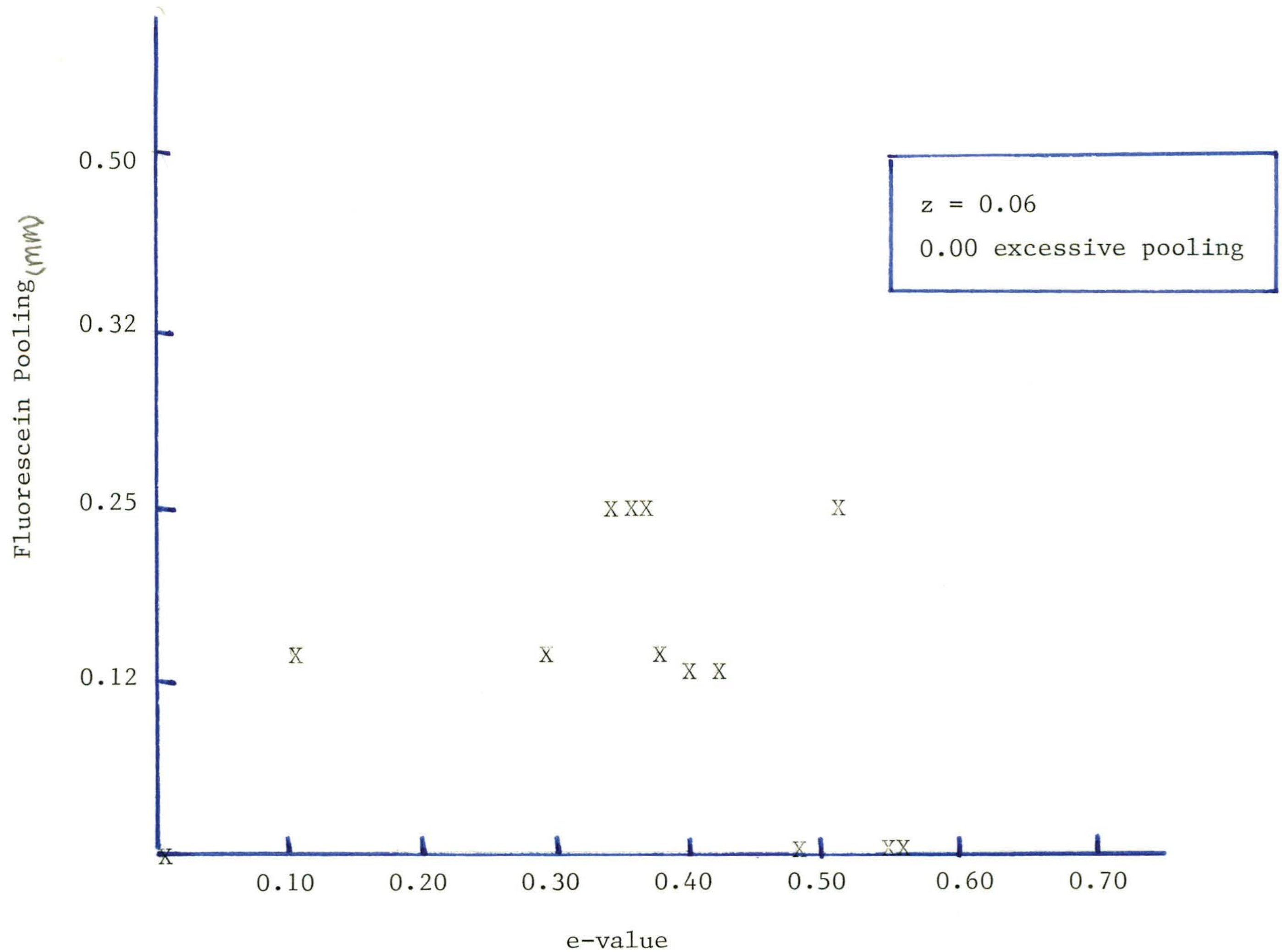

0.50
0.32
0.25
0.12
Fluorescein Pooling (mm)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
e-value
z = 0.141
Uneven
Peripheral Pooling
0.00 excessive
0.00 excessive
0.30 excessive

FIGURE 4



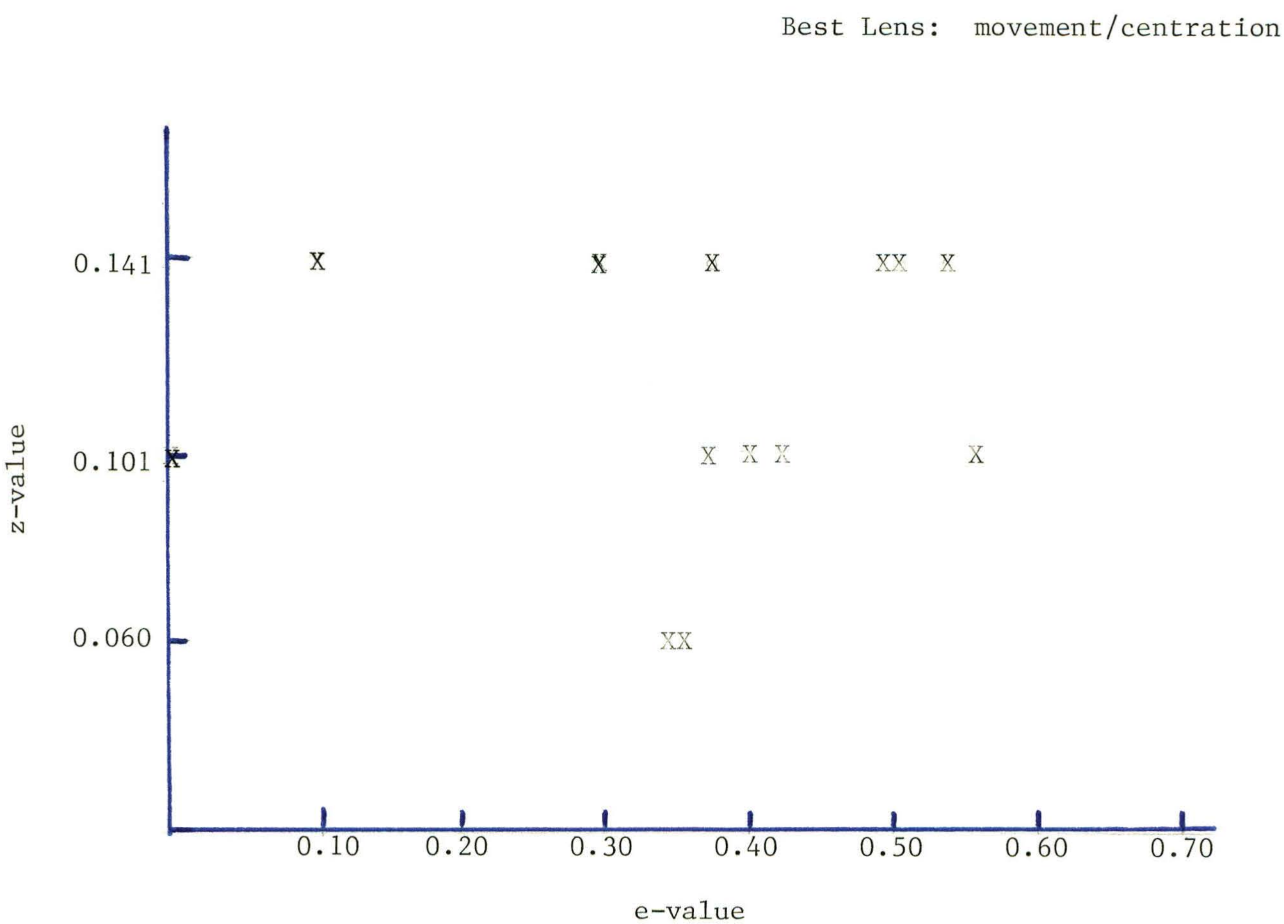
Fluorescein Pooling (mm)
0.50
0.32
0.25
0.12
z = 0.10
0.00 excessive
0.10
0.20
0.30
0.40
0.50
0.60
0.70
e-value

FIGURE 5



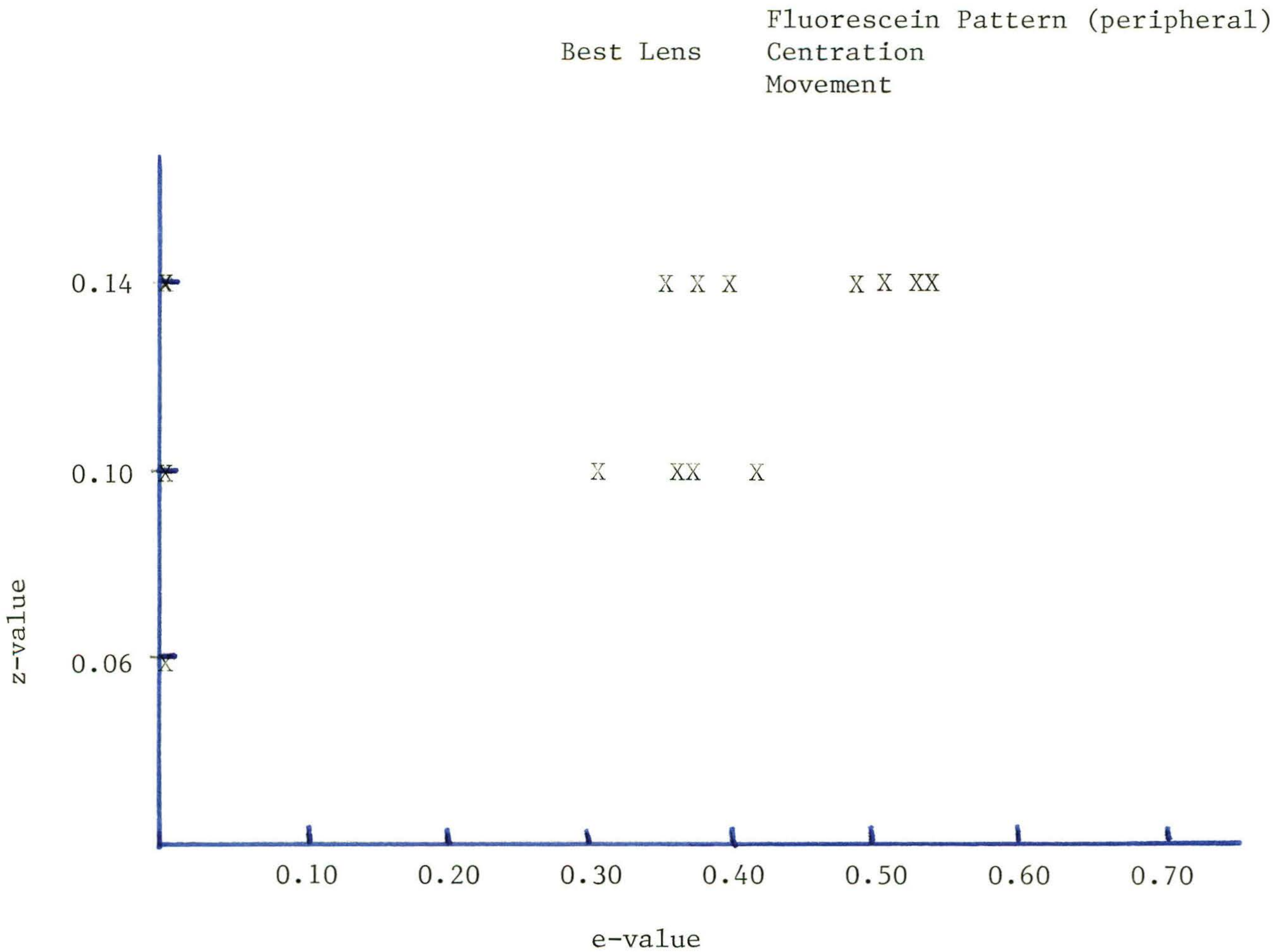
z = 0.06
0.00 excessive pooling
Fluorescein Pooling (mm)
0.50
0.32
0.25
0.12
0.10
0.20
0.30
0.40
0.50
0.60
0.70
e-value

FIGURE 6



Best Lens: movement/centration
0.141
0.101
0.060
z-value
0.10
0.20
0.30
0.40
0.50
0.60
0.70
e-value

FIGURE 7


Best Lens
Fluorescein Pattern (peripheral)
Centration
Movement
0.14
0.10
0.06
z-value
0.10
0.20
0.30
0.40
0.50
0.60
0.70
e-value