COMPARISON OF BACK-SURFACE ASPHERIC, RIGID CONTACT LENSES: POWER DISTRIBUTION, ECCENTRICITY, AND ADD CHANGE

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ABSTRACT

The Corneal Analysis System was used to measure the back surface of Goldberg APA aspheric rigid multifocal contact lenses in order to calculate the contact lens' eccentricity, average and specific. A modified lensometer stop was used to measure the power of these contact lenses at specific points at a known distance from the center of the lens to determine the change in power across the back surface of the lenses. The results showed that the change in power from the center of the lens to the edge varied based upon the eccentricity and apical radius of the lens; therefore, when fitting a patient with aspheric RGPs, the contact lens practitioner must consider the relationship between eccentricity, apical base curve, and add change.

INTRODUCTION

Aspheric contact lenses have been available for many years. More recently have eye care practitioners used them to provide assistance to the presbyopic patient. The simultaneous, concentric design enables the patient to obtain an add power for near vision at any point distant from the center of the lens. Although it sounds simple, patients have had difficulty achieving proper add power, and so, stable, comfortable near vision has been difficult to maintain.

The first step for the lenses to be clinically effective lies in the hope that the manufacturers can produce a lens by controlling the rate of flattening, or eccentricity, and then to controllably reproduce it. There are many techniques that manufacturers use to create an aspheric surface. The common tri-curve RGP is not an aspheric but rather has three circular curves separated by transition zones, or blends. An aspheric surface is produced by a gradual flattening of curvature from apex to periphery that can be considered to have no transition zones.(1) The eccentricity, or e-value, of a lens increases as the rate of flattening increases or as the sagittal depth decreases from the apex of the lens to the edge of the lens.

A circle has an e-value of zero; whereas, conicoids have e-values greater than zero. **Table** I lists the eccentricity and shape of aspheric surfaces.(2) Some researchers believe that an aspheric RGP that is designed after true conicoids, rather than an off-set sphere or pseudo-conicoids, yield better reproducibility, control of curvature and offer superior quantitative and qualitative vision.(3,4)

Clinical success relies on the ability of the practitioner to accurately verify the asphericity of the contact lens. The Volk Eccentriscope is a radiuscope with a tilting device that can measure the peripheral curves of an aspheric surface, but it is not designed to measure values from finished RGP lenses.(4-6) Manufacturers may use interferometry to measure the peripheral curvatures of an aspheric surface, but it is quite expensive and not practical for most clinicians.(7)

The purpose of this study was to investigate the relationship between eccentricity and apical base curve and their effect on power distribution across the back-surface of an aspheric RGP. The Eyesys Corneal Analysis System was used to analyze the posterior surface of the Goldberg APA lens, an aspheric RGP which is used for correcting presbyopia. By using a computer assisted videographic unit, a very reliable description of the posterior surface of the aspheric lenses was made. From there, calculations were made to assess the eccentricity of the lenses.

It was hopeful that the e-value of each of the lenses would remain constant. This would help support the idea that the steeper lenses would show greater add change than would the flatter lenses.(6) If the rate of flattening was shown to be inconsistent, then the add changes would be expected to vary based upon the amount of eccentricity and the apical base curve of the lens.(11)

METHODS

Six Goldberg APA lenses obtained from the manufacturer were measured in the study. Three lenses were labeled -3.00DS with apical base curves of 6.70, 6.80, and 7.09mm. One lens was labeled -5.00DS with an apical base curve of 6.90mm. Another lens was labeled -2.00DS with an apical base curve of 7.01mm, and the remaining lens was labeled -2.50DS with an apical base curve of 7.20mm. Each of the lenses were manufactured to have a similar eccentricity and design characteristics.

First, the Eyesys Corneal Analysis System was used to quantify the back surface of parameters of each of the lenses. The Eyesys has the capability to evaluate convex surfaces such as the cornea and the front surfaces of contact lenses. In addition, calibration data stored within the computer program can be inverted so that concave surfaces, such as the posterior surfaces of RGP buttons and finished RGPs, can be measured.(8)

Each lens was carefully placed in the mounting unit supplied by Eyesys and positioned according to the manufacturers recommendations.(8) After each lens was centered, the automated photokeratoscope, or Eyesys, projected a Placidos' disc on the back surface of the lens. When the image of the discs was centered equally on the lens, the Eyesys was focused until the images first became clear. A computerized photograph of the reflected image was taken at that instant and the data was analyzed by the Eyesys method of electronic image processing.(8)

After each reading, the lens was rotated on the mounting unit, carefully recentered, and then re-analyzed. Each of the six lenses was measured five times. Due to the decrease in the quality of the reflected image toward the edge of the lens, accurately repeatable data could only be obtained for radii of 4mm, or 8mm chord diameter(8mmCD).

The mean, standard deviation, and eccentricity of each lens was calculated. The mean and standard deviations were calculated using simple computations. Eccentricity was calculated using the equation(7):

$$e = \sqrt{\frac{Rs^2 - Ro^2}{y^2}}$$

where e = eccentricity,
Rs = sagittal radius,
Ro = apical radius,
y = distance of the measured point from the apex.

Next, the central distance power of the lenses was measured using a standard lensometer. Each lens was measured five times each. The power of the lenses peripheral to the center of the lenses was measured by a home-made lensometer stop similar to that used by Buckingham and Lowther, as suggested by Korb.(6,9) The stop was made by using the bottom (convex) side of a disposable contact lens case. The convex surface was colored black which made measurements easier due to reduced reflections.

Two small holes, approximately .75mm in diameter, were positioned equidistant from the center of the stop. Similar to Buckingham and Lowther, it was found that any hole smaller than .50mm in diameter caused too much diffraction to obtain reliable readings. Also, the smallest hole possible was desired so that measurements would be taken from a specific point rather than a general location.

When measuring a contact lens with this modified stop, the Scheiners' disc created by the two apertures was only seen as single when in focus. Therefore, reliable and accurate readings could be made as long as the image was single regardless of clarity.(6)

Five stops were designed so that each would have a different separation distance between holes. Aperture stops were labeled 2.0, 3.0, 4.0, 5.0, and 6.0mm. When power measurements were taken from these stops, they represented peripheral power points from the center of the lens of 1.0, 1.5, 2.0, 2.5, and 3.0mm, respectively. No greater separations could be assessed due to the 6.0mm aperture of the standard American Optical lensometer used.

In order to obtain reliable readings, the modified stop and each lens was dotted in the center with a fine tipped permanent marker. The center of each was determined by using the boxing method: the intersection of the diagonals of a square. This allowed for accurate centering of each lens on each stop. Because each stop was colored with black marker, the stop surface was sticky. As each lens was centered and mounted on the stop, they adhered to the stop. This resulted in stable, maintainable centering. Each lens was measured five times on the five different aperture stops. The mean, standard deviation, and add changes, or power changes, were calculated for each lens.

RESULTS

The geometry of the posterior surface of the lenses determined by the Eyesys Corneal Analysis System showed great accuracy and repeatability. See **Tables IIa - IIf**. The largest standard deviation of all points was +/- .012mm. This proves that proper centering and mounting was established.

Figure III is a plot of the rate of flattening from the center of the lenses to the periphery(up to 8mmCD). The Aspheric finished RGPs showed consistent flattening from the apex to approximately 4mmCD peripherally. From 4mmCD to 8mmCD, they showed a consistent decrease in eccentricity.

The difference in e-values measured by the Eyesys at different points on each of the lenses shows that the lenses were not an exact design of a conic section. This can easily be seen by the accuracy and repeatability of the topographic measurements which shows variability in design most likely due to the manufacturing difficulty of an aspheric surface. Color maps of each lens reaffirm the geometry of the lenses and give an easy-to-read picture of the design of the posterior surface. See topographic **Color Map**.

The use of the modified aperture stops with lensometry to measure the peripheral points of the lenses was simple and repeatable. The largest difference in measurements for all points was +/-.25D which correlated to a standard deviation of +/-.11D. The average power, standard deviation, and theoretical add change for each lens can be seen in **Table IVa - IVf**.

A plot of the average power change from the center of the lenses to the periphery is shown in **Figure V**. As can be seen, the lens with the steepest apical base curve radius(6.70mm), showed the greatest amount of power change. In addition, the lens with the flattest apical base curve radius(7.20mm) showed the lowest amount of power change. Overall, the six lenses showed a consistent power change from the apex of the lens to the periphery(6mmCD).

More specifically, the lenses were compared at a point 2.0mm from the center of the lens. A plot of the power change at 2.0mm from the center of the lens for each of the six lenses can be seen in **Figure VI**. The plot shows the general relationship between the apical base curve and the amount of power change. The steeper lens has a greater power change than the flatter lenses.

DISCUSSION

It was stated by Goldberg that the specific design of the APA lens was to yield a lens with an e-value of approximately 1.0.(10) Therefore, this design would be parabolic in nature and would produce increased flattening from the center of the lens to the periphery. The flattening rate would provide greater plus power through the peripheral portion of the lens. The APA lenses were aspherically lathe cut and aspherically polished to provide more precise manufacturer reproducibility.(10)

To follow up, it was indeed found that for the most part the calculated e-value approximated 2.0 for a chord diameter of 1-4mm. Furthermore, the stable design of the APA lens was supported by the fact that the steeper lenses were shown to have a greater power change from apex to the edge as compared to the flatter lenses.

CONCLUSION

The Eyesys System was used to accurately describe the posterior surface design of the aspheric RGP, the Goldberg APA. Color maps produced demonstrate the gradual flattening of the lens from apex to edge.

The modified lensometer stop made measurements of the aspheric lens simple and accurate. The measurements provided by this technique show the relationship between the apical base curve and the amount of power change. The power change is greater for steeper lenses than for flatter lenses.

Table VII shows the average e-value and the average power change for the APA lenses at 2.0mm from the center of the lenses. The calculations of the eccentricity show that the actual e-value at 2.0mm varies from lens to lens; and so, the steepest lens does not have the highest e-value.

One could conclude that if all of the lenses had the same apical base curve, the lens with the highest e-value would also have the greatest amount of power change. However, for all aspherics there exists a relationship between the apical base curve, eccentricity, and add change. As long as the e-values remain similar(in this case, all APA lenses approximate 1.0), the lens with the steepest apical base curve will show the greatest add change. If e-values for the lenses were not controlled, then the steepest lens would not necessarily have the highest add change. For this example, the lens with the highest e-value would provide much more peripheral flattening, and therefore, more add change.

Because of the variability of aspheric lenses, a contact lens practitioner would expect less than stable success when prescribing aspheric lenses.(11) Determining the e-values and power distribution across the lens will allow the clinician better quality control.

Since it is very time consuming to determine e-values, it would be best to find an RGP manufacturer that produces a quality lens with design parameters that state average e-values. This ensures that the steps to improve reproducibility by the manufacturer have been taken. Next, simple measurements with a modified lensometer stop to assess average add powers could be made in order to label each lens. These lenses could comprise a trial lens set that is labeled by specific add power and base curves instead of by e-values and base curves. This would aid in determining the proper diagnostic lens for each patient.

For example, in a trial lens set that has a specific e-value, each lens can be measured to have a different add power. Since the apical base curve that yields proper alignment for one patient may be significantly different for another, there will be some patients who obtain larger add powers than others; and so, the optical result will vary from patient to patient.

It is true that not all aspheric RGPs have a consistent rate of flattening with consistent add changes. It is also true that not all presbyopes require the same add - whether it is the amount of presbyopia or occupational needs. It is this variability in patient demands that will challenge the contact lens practitioner to consider lens design, apical base curve, and power change that will best benefit the patient's needs.

REFERENCES

1. Bennett, AC., "Aspherical Contact Lens Surfaces." Ophthalmic Optician, 1969;8:1037.

2. Barr, Joseph T., "Aspheric Update 1988 Part I", Contact Lens Spectrum, November,1988:56-60.

3. Ruben, M., "The Fitting of Corneal Lenses." Contact Lens Practice, 1975;156-172.

4. Goldberg, Joe B., and Caroline, Patrick, "Getting The Reproducibility You Want in Aspheric Lenses", Contact Lens Spectrum, December, 1994; 31-35.

5. Volk, D., Method and Apparatus for Determining the Eccentricity of a Conicoid Surface. U.S. Patent #3,482,904, December 9, 1969.

6. Buckingham, Robert, and Lowther, Gerald E., "Power Distribution Across a Back-Surface Aspheric, Rigid Multifocal Contact Lens", International Contact Lens Clinic, July/August 1982: (9)4, 213-17.

7. DeFazio, Anthony J., and Lowther, Gerald E., "Inspection of Back Surface Aspheric Contact Lenses", American Journal of Optometry and Physiological Optics, August 1979: 471-79.

8. Eyesys Corneal Analysis System, Owners Manual-Guide.

9. Korb, D. Read before the CSI Launch Symposium; Scottsdale, AZ, January 9-10, 1981.

10. Goldberg, Joe B. GBF Contact Lenses Inc.

11. Goldberg, Joe B., "How and When to Prescribe Aspheric Lenses", Review of Optometry, June 1989: 47-53.

TABLE I: ECCENTRICITY (VS) LENS SHAPE

e-value	LENS SHAPE
$e = 0$	Circle
$0 < e < 1$	Ellipsoidal
$e = 1$	Paraboloidal
$e > 1$	Hyperboloidal

TABLE IIa: 6.70b.c.

CD	$\overline{X}$	SD±	e-value
0	6.70	.007	.000
1	6.72	.004	.927
2	6.70	.006	.884
3	6.85	.005	.931
4	6.94	.005	.893
5	6.99	.005	.789
6	7.09	.010	.767
7	7.16	.007	.722
8	7.22	.010	.670

TABLE IIb: 6.80b.c.

CD	$\overline{X}$	SD±	e-value
0	6.80	.006	.000
1	6.82	.007	.990
2	6.86	.012	.920
3	6.97	.010	1.032
4	7.09	.006	1.004
5	7.15	.008	.889
6	7.31	.008	.898
7	7.40	.008	.837
8	7.50	.004	.790

TABLE IIc: 6.90b.c.

CD	$\overline{X}$	SD±	e-value
0	6.90	.006	.000
1	6.91	.005	.880
2	6.97	.004	.971
3	7.06	.000	.996
4	7.15	.000	.937
5	7.24	.004	.880
6	7.41	.004	.902
7	7.51	.004	.849
8	7.58	.005	.787

TABLE IId: 7.01b.c.

CD	$\overline{X}$	SD±	e-value
0	7.01	.010	.000
1	7.02	.008	.670
2	7.07	.005	.964
3	7.16	.005	.991
4	7.24	.004	.905
5	7.35	.004	.884
6	7.47	.004	.864
7	7.60	.004	.842
8	7.67	.004	.781

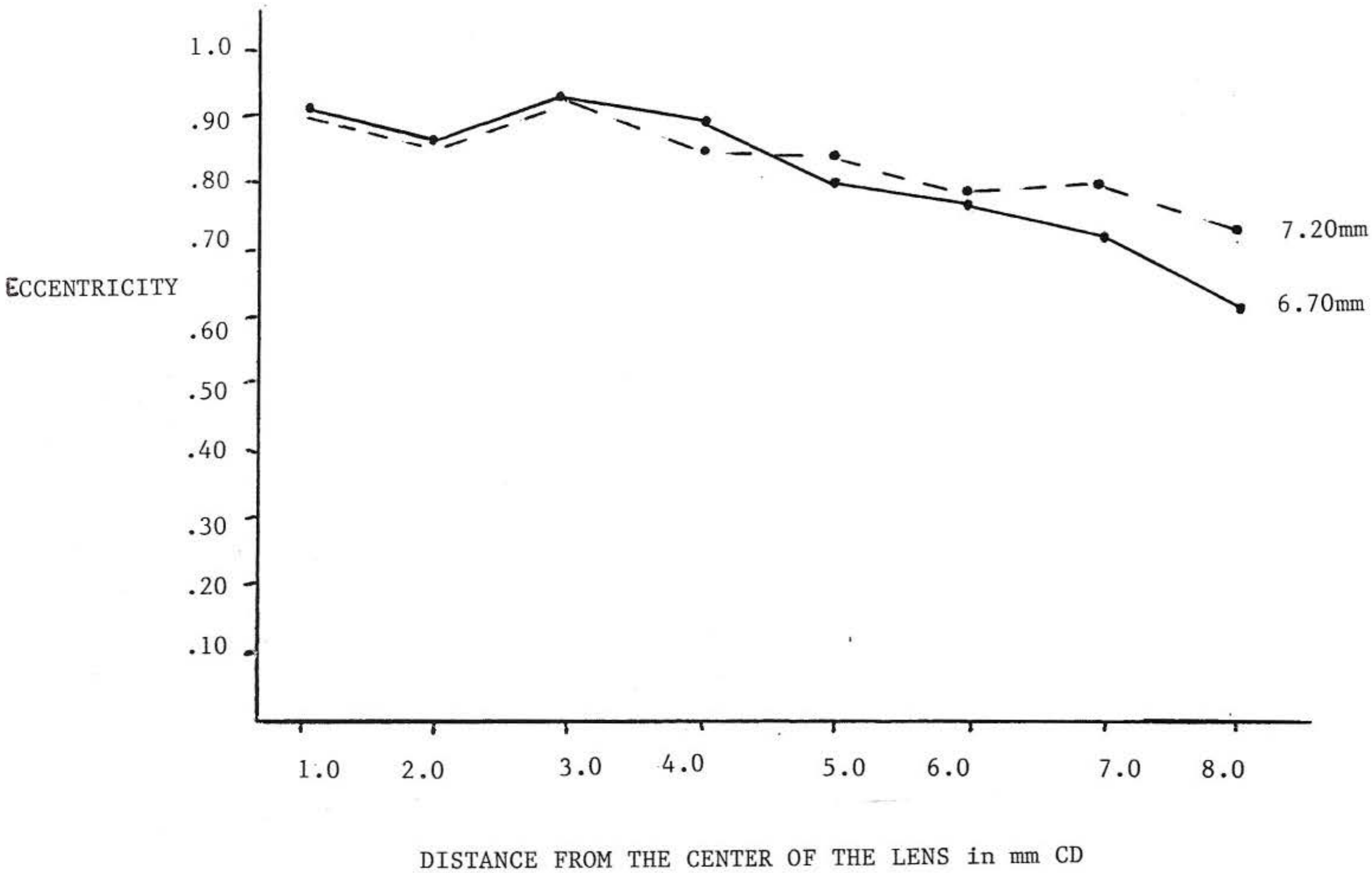
TABLE IIe: 7.09b.c.

CD	$\overline{X}$	SD±	e-value
0	7.09	.007	.000
1	7.10	.010	.476
2	7.15	.007	.924
3	7.23	.005	.951
4	7.29	.000	.884
5	7.37	.000	.802
6	7.45	.004	.763
7	7.56	.005	.745
8	7.62	.006	.697

TABLE IIf: 7.20b.c.

CD	$\overline{X}$	SD±	e-value
0	7.20	.005	.000
1	7.20	.005	.000
2	7.25	.000	.883
3	7.33	.000	.930
4	7.38	.000	.819
5	7.49	.000	.831
6	7.56	.004	.775
7	7.73	.004	.805
8	7.80	.004	.751

FIGURE III: RATE OF FLATTENING FROM APEX TO EDGE



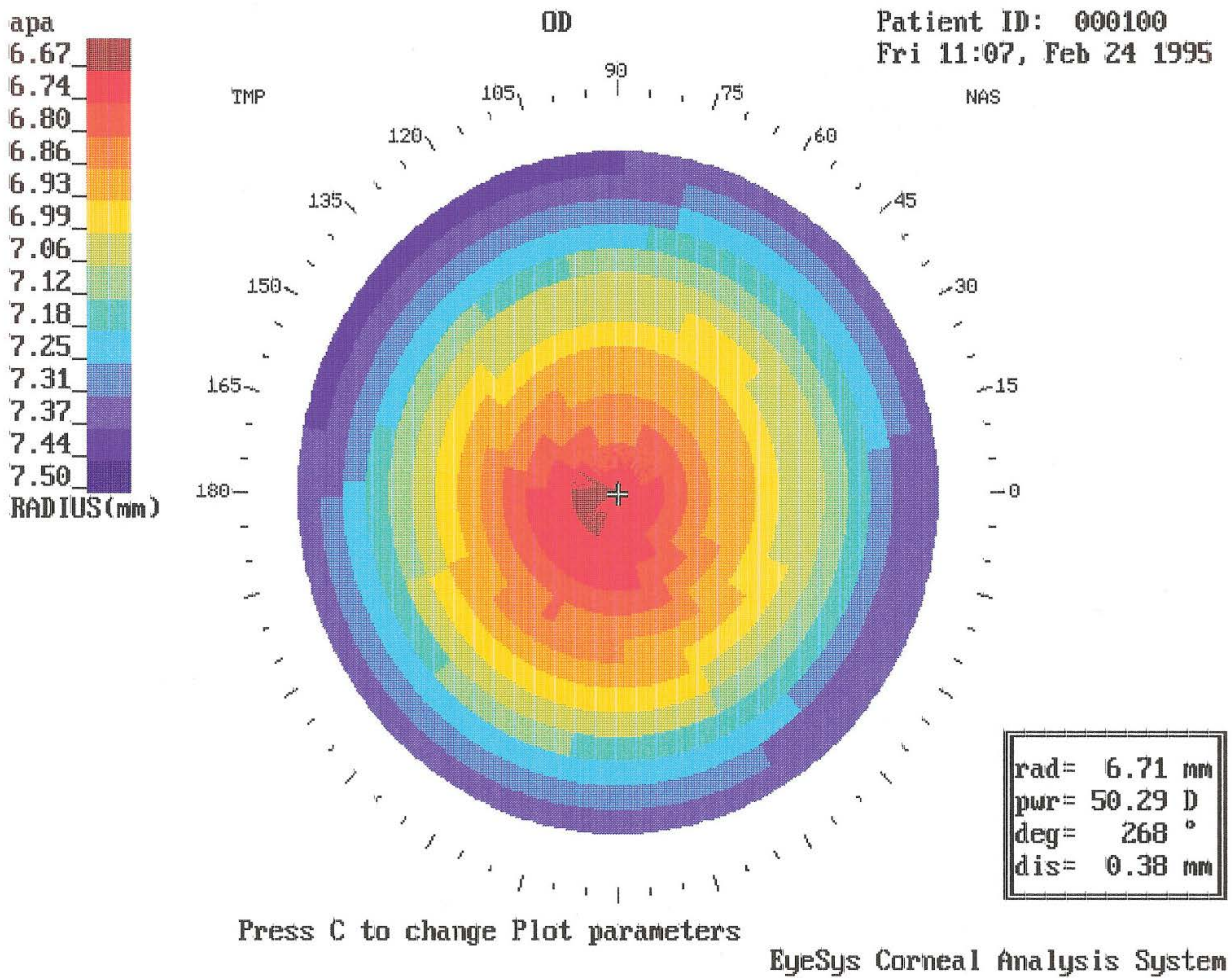

apa
6.67
6.74
6.80
6.86
6.93
6.99
7.06
7.12
7.18
7.25
7.31
7.37
7.44
7.50
RADIUS(mm)
OD
Patient ID: 000100
Fri 11:07, Feb 24 1995
TMP
NAS
90
105
75
120
60
135
45
150
30
165
15
180
0
rad= 6.71 mm
pwr= 50.29 D
deg= 268 °
dis= 0.38 mm
Press C to change Plot parameters
EyeSys Corneal Analysis System

TABLE IVa: 6.70b.c., -3.00DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-3.00	.000	0.0
2	-2.20	.066	0.80
3	-1.00	.088	2.00
4	+0.80	.071	3.80
5	+1.93	.111	4.93
6	+4.00	.000	7.00

TABLE IVb: 6.80b.c., -3.00DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-3.00	.000	0.0
2	-2.20	.066	0.80
3	-1.05	.071	1.95
4	+0.57	.099	3.57
5	+1.78	.058	4.78
6	+3.25	.000	6.25

TABLE IVc: 6.90b.c., -5.00DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-5.00	.000	0.0
2	-4.25	.000	0.75
3	-3.00	.000	2.00
4	-1.25	.088	3.75
5	-0.48	.054	4.52
6	+0.95	.066	5.95

TABLE IVd: 7.01b.c., -2.00DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-2.00	.000	0.0
2	-1.50	.000	0.50
3	-1.25	.000	0.75
4	+0.25	.000	2.25
5	+1.55	.071	3.55
6	+3.00	.000	5.00

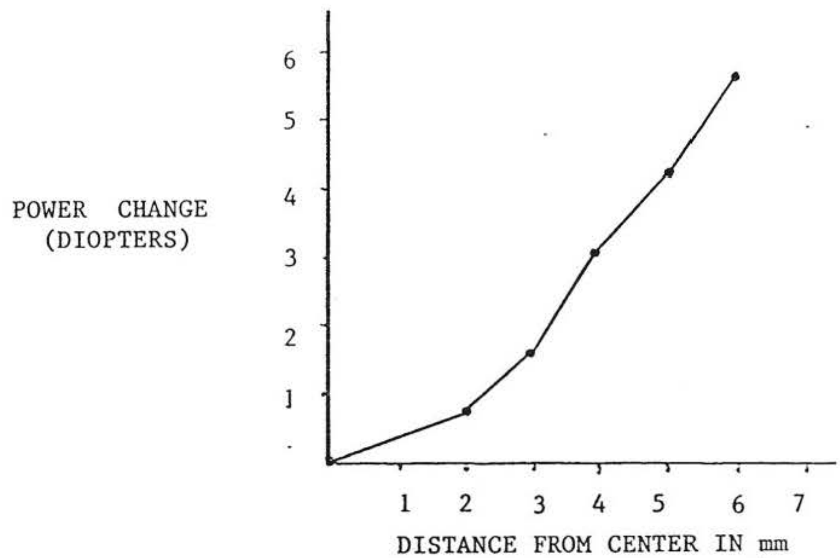
TABLE IVe: 7.09b.c., -3.00DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-3.00	.000	0.0
2	-2.23	.054	0.77
3	-1.23	.054	1.77
4	+0.05	.071	3.05
5	+1.03	.058	4.03
6	+2.03	.058	5.03

TABLE IVf: 7.20b.c., -2.50DS

CD	$\bar{X}$	SD±	ADD CHANGE
0	-2.50	.000	0.0
2	-1.78	.058	0.72
3	-1.00	.000	1.50
4	+0.03	.058	2.53
5	+1.00	.000	3.50
6	+2.20	.066	4.70

FIGURE V: AVERAGE POWER CHANGE FROM APEX TO EDGE



MEAN ADD CHANGE IN DIOPTERS

CD \ BC	6.70	6.80	6.90	7.01	7.09	7.20	$\overline{X}$ ADD CHANGE
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.80	0.80	0.75	0.50	0.77	0.72	0.72
3	2.00	1.95	2.00	0.75	1.77	1.50	1.66
4	3.80	3.57	3.75	2.25	3.05	2.53	3.16
5	4.93	4.78	4.52	3.55	4.03	3.50	4.22
6	7.00	6.25	5.95	5.00	5.03	4.70	5.67

FIGURE VI: POWER CHANGE AT 2.00mm FROM APEX TO EDGE

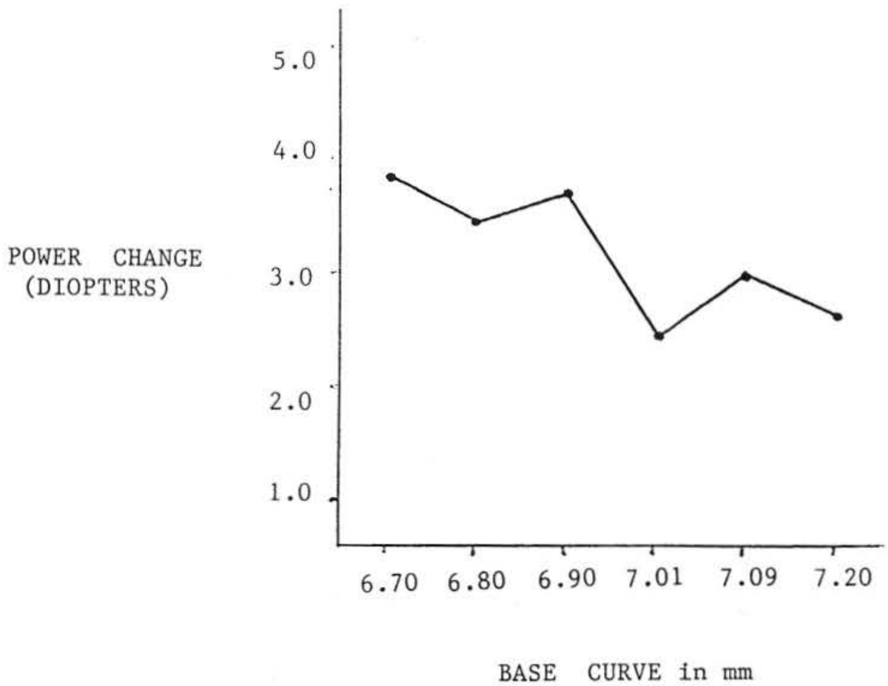


TABLE VII: MEAN e-value AND MEAN POWER CHANGE AT 2.00mm FROM APEX

BC	LENS POWER	MEAN ADD CHANGE	SD: X ADD CHANGE	MEAN e-value	SD MEAN e-value
6.70	-3.00	3.80	.07	.88	.01
6.80	-3.00	3.57	.09	.92	.01
6.90	-5.00	3.75	.09	.97	.004
7.01	-2.00	2.25	0.0	.96	.01
7.09	-3.00	3.05	.07	.92	.01
7.20	-2.50	2.53	.06	.88	0.0