1976

The effects of corneal eccentricity on the supplemental power effect of Bausch and Lomb Soflens contact lenses

John M. Dahl
Pacific University

William D. Faulkner
Pacific University

Recommended Citation

Dahl, John M. and Faulkner, William D., "The effects of corneal eccentricity on the supplemental power effect of Bausch and Lomb Soflens contact lenses" (1976). *College of Optometry*. 421.
https://commons.pacificu.edu/opt/421

The effects of corneal eccentricity on the supplemental power effect of Bausch and Lomb Soflens contact lenses

Abstract

The effects of corneal eccentricity on the supplemental power effect of Bausch and Lomb Soflens contact lenses

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Don C. West

Subject Categories

Optometry

THE EFFECTS OF CORNEAL ECCENTRICITY
ON THE
SUPPLEMENTAL POWER EFFECT
OF
BAUSCH AND LOMB SOFLENS^{tm}
CONTACT LENSES

A SIXTH YEAR THESIS
PRESENTED TO
THE FACULTY OF THE COLLEGE OF OPTOMETRY
PACIFIC UNIVERSITY

IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE
DOCTOR OF OPTOMETRY

BY
JON M. DAHL
WILLIAM D. FAULKNER
DON C. WEST, O.D., ADVISOR

Doctoral thesis in partial
fulfillment of the requirement for
the degree of Doctor of Optometry from
Pacific University College of Optometry

Advisor Approval

D. C. West

Don C. West, O.D.

CONTENTS

I. Introduction

Since the introduction of the Bausch and Lomb SOFLENS^{tm} in this country, there have been reports of a difficulty in determining the proper effective back vertex power for the correction of a patient's refractive error. This difficulty has led several investigators to evaluate the many factors that might contribute to the power of the optical system that is created when the SOFLENS^{tm} is placed on the eye.

According to Kaplan[1], the factors that alter the power of a flexible contact lens when placed on the eye can be placed into two categories:

1) Unpredictable Optical Effects - elasticity, surface tension, resiliency of material, capillary and lid pressures, etc.

2) Predictable Optical Effects - "bending"

To illustrate the effects of this bending on the power of a flexible lens, Kaplan describes a lens whose anterior and posterior surfaces are parallel. He makes the assumption that as the posterior surface is bent, the anterior surface will remain parallel to it while the thickness remains unchanged throughout. Also, the elasticity of the lens, its surface tension and the forces that bend the lens to its new curvature are assumed to not change the relationship of the surfaces or the thickness.

Given the above prerequisite conditions, Kaplan demonstrates that as the lens is bent to steeper curvatures, there is a resultant increase in negative dioptric power. Conversely, as the lens surfaces are flattened, there is an increase in positive dioptric power.

Sarver[2] maintains that the power effect of a flexible contact lens placed on the eye is a function of the following:

1) the back vertex power of the lens as measured in air

2) the manner in which the lens flexes on the eye

3) the power of the fluid lens formed between the lens and the cornea

The fluid lens power is dependent upon the conformation of the lens to the corneal surface, i.e. the lens "flexure", item #2 above. The combination of the lens flexure and the fluid lens has been labeled "supplemental power effect" by Sarver. The flexure of the lens is considered "positive" when there is an increase in curvature and considered "negative" when there is a decrease in curvature, or flattening.[2]

The dioptric effect of the flexure of the lens will cancel some portion of the fluid lens power when the changes in flexure occur.[2] Therefore, as the "positive" flexure occurs, the fluid lens becomes more positive in dioptric power while the effect of the curvature changes on the lens surfaces is in the negative direction. As the "negative" flexure occurs, the fluid lens becomes more negative, while the effect of the surface curvature changes on the lens power is in the positive direction.

Any changes in the fluid lens power may not be attributed to any change in the corneal topography, which is shown to remain relatively constant with flexible lens wear. Studies by Bailey and Carney[3] and Hill[4] confirm this fact.

The uncertainty in the choice of the appropriate lens to be used to correct a given eye's refractive error led Touch[5] to the development of the "Best- Fit" formula. This "Best- Fit" formula is currently promoted by Bausch and Lomb for the fitting of their SOFLENS^{tm}.

Even with the utilization of Touch's elaborate system for the prescribing of the SOFLENS^{tm}, idiosyncratic fluctuations in the effective power of a lens can be found when it is placed on an eye.

In an attempt to account for these differences, Sarver[6] demonstrated that there was a significant correlation between the supplemental power effect and the apical lens/ cornea bearing relationship. A large variance in this relationship suggests, however, that several other factors may also affect the supplemental power. Sarver suggests that corneal eccentricity (peripheral flattening) could be a factor and should be investigated.

This study will investigate the possibility that a variation in corneal eccentricity may produce different amounts of lens flexure, which will secondarily affect the total supplemental power effect.

Eccentricity is a mathematical construct used to describe the different classes of curves that may be derived from a conic section. A numerical value is assigned to each type of curve, so the eccentricity is similarly assigned a numerical value.

Each conic curve can be described in terms of the relationship of the curve to a fixed point (focus) and a fixed line (directrix). For each point of a given conic curve, there will be a specific ratio between the distance to the focus and the distance to the directrix. This ratio (d_f/d_d) will provide the numerical value used to describe the eccentricity for the curve.

For a circle, the ratio of the distance to the focus to the distance to the directrix is 0.0. For the family of curves called ellipses, the ratio is greater than 0.0, but less than 1.0. The parabola has a ratio of 1.0. The family of curves called hyperbolas have a ratio that is greater than 1.0. Figure 1 (page 5) illustrates the relationship of the different conic curves[7].

It can be seen from Figure 1 that the curves have a common central radius, but they differ in the amount of peripheral flattening.

Figure 2 (page 5) demonstrates how this concept of eccentricity relates to the corneal topography[8].

If a correlation is found between corneal eccentricity and the supplemental power effect, the the practicioner may

Figure 1:

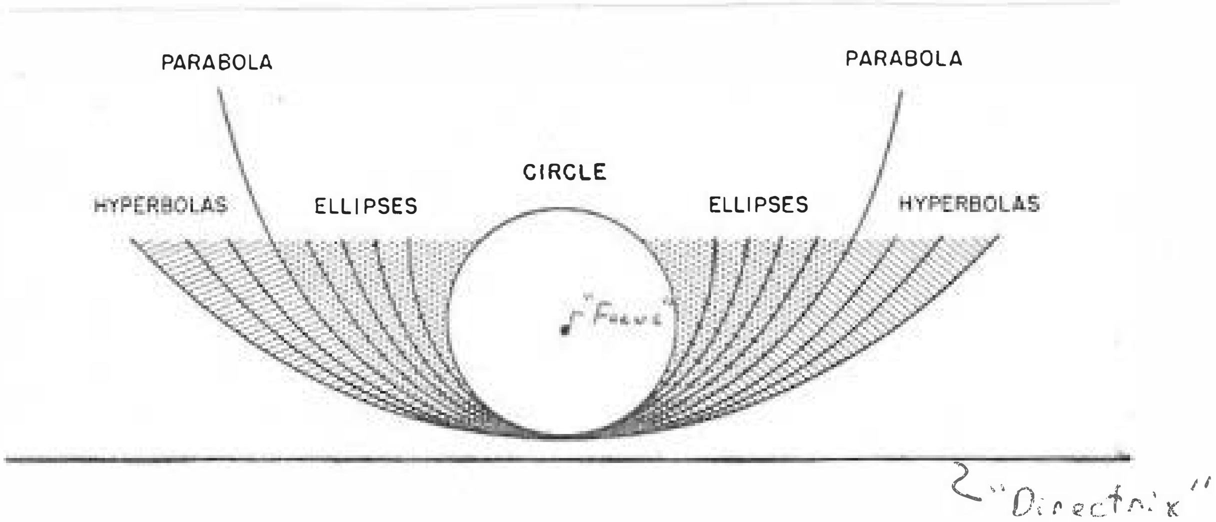
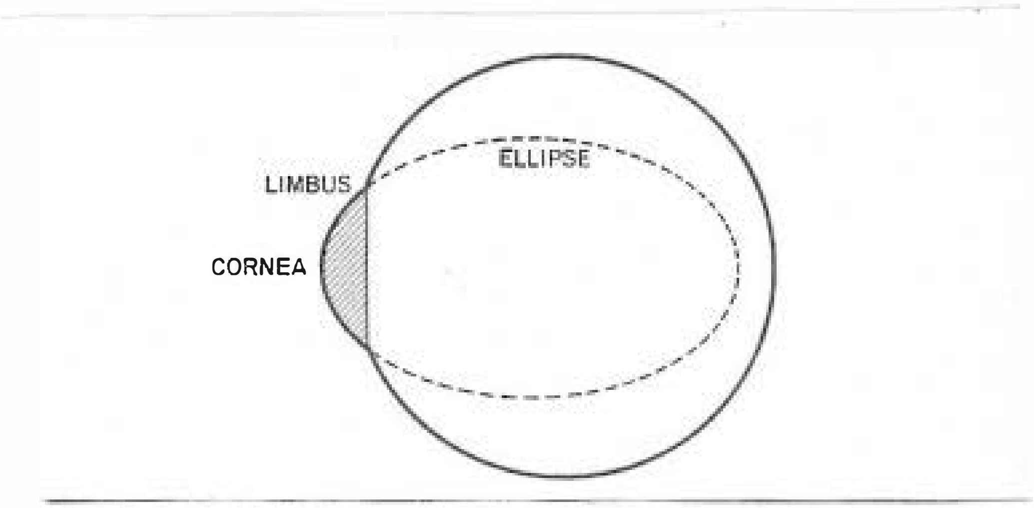


Figure 2:



then be better able to predict the power effects of a given B & L SOFLENS^{tm} on a cornea.

II. Procedure

This study of the supplemental power effect as influenced by eccentricity consists of two portions:

1) using a corneal analog (anterior aspheric PMMA lens) with varying eccentricities

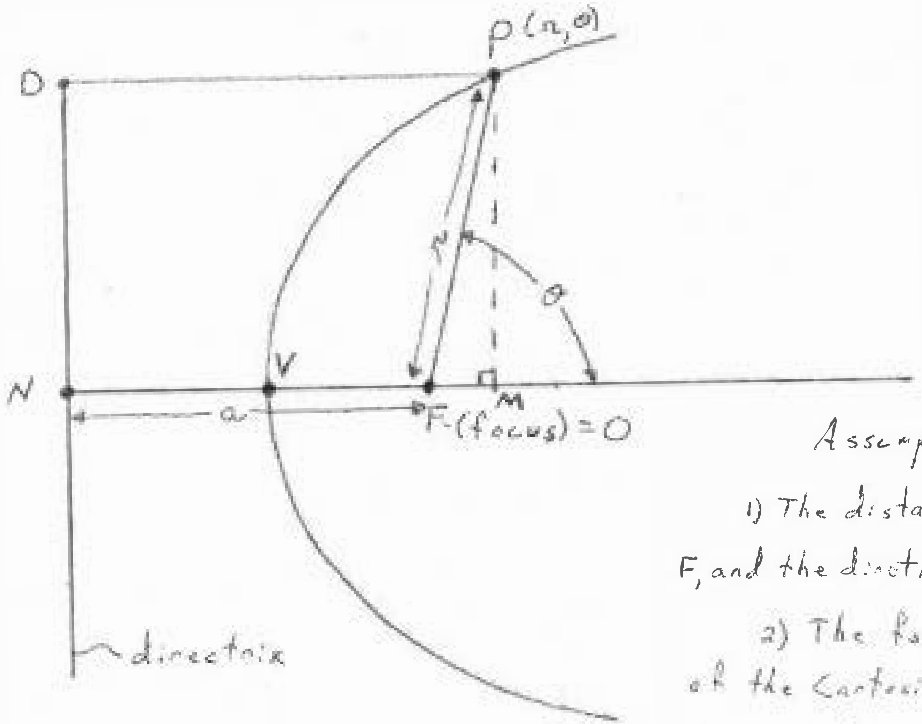
2) using human corneas whose eccentricities have been measured by the Wesley/Jessen Photoelectric Keratoscope

Since anterior aspheric lenses are not routinely manufactured with varying eccentricities, it became necessary to design the parameters of such lenses. A mathematical formula which incorporates the eccentricity value was derived to describe the curvatures on the anterior aspheric lenses. The derivation, which utilizes a polar coordinate system, is on pages 7 and 8.

Using the formula:

$$r = \frac{e\,a}{1 - e\cos\theta}$$

- the r value, or the distance from the focus to the curve, was calculated at ten degree intervals. The locus of points defined by this process was drawn at ten times the actual size.



Assumptions:

1) The distance between the focus, F, and the directrix is a

2) The focus, F, is the origin, O, of the Cartesian x, y system, the x-axis being along the line NM, and the y-axis passing through F, parallel to the directrix.

$$e = \frac{\overline{PF}}{\overline{PD}}$$

$$\overline{FM} = r\cos\theta$$

$$\overline{PD} = \overline{NM} = \overline{NF} + \overline{FM} = a + r\cos\theta$$

$$e = \frac{r}{a + r\cos\theta}$$

$$ea + er\cos\theta = r$$

$$ea = r - er\cos\theta = r(1 - e\cos\theta)$$

$$* \quad r = \frac{ea}{1 - e\cos\theta}$$

$\overline{VF}$ = Anterior Apical Radius for each lens.

to solve for $\overline{VF} \Rightarrow \theta = \pi \Rightarrow \therefore \; r_{\overline{VF}} = \frac{ea}{1 - e\cos\pi} = \frac{ea}{1+e}$

(Negative cosine values will be used with this equation)

Therefore, with the anterior aspheric lenses having an anterior apical radius of 7.8 mm, $\overline{VF} = 7.8\text{mm} = \frac{ea}{1+e}$

Since the a value will change, depending on the eccentricity value of the lens. If $7.8\text{mm} = \frac{ea}{1+e}$, Then $a = \frac{7.8\text{mm}(1+e)}{e}$

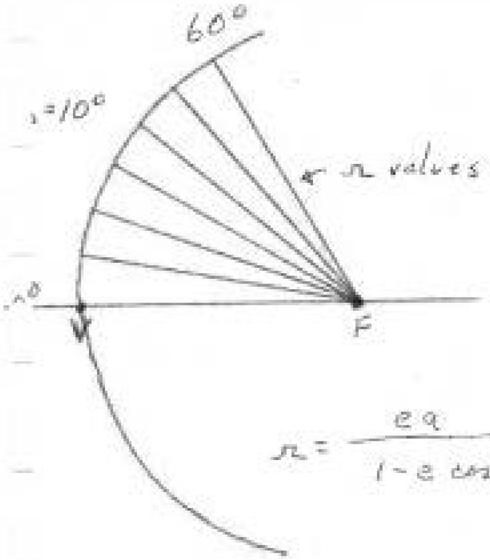
a values:

Eccentricity

0.0	0.2	0.4	0.6	0.8	1.0
X (Sphere)	46.8mm	27.3mm	20.8mm	17.55mm	15.6mm

The a values are necessary to calculate the various r values for each lens.

The following table is a list of r values for each lens, going from 0°(R) to 60°, in 10° intervals:



$$r = \frac{ea}{1 - e\cos\theta}$$

Eccentricity

	0.0	0.2	0.4	0.6	0.8	1.0
0°	7.8	7.8	7.8	7.8	7.8	7.8
10°	" (Spherical)	7.82	7.83	7.84	7.85	7.86
20°	"	7.88	7.94	7.98	8.01	8.04
30°	"	7.98	8.11	8.21	8.29	8.36
40°	"	8.12	8.36	8.55	8.71	8.83
50°	"	8.29	8.69	9.01	9.27	9.49
60°	"	8.51	9.10	9.60	10.03	10.40

(r in millimeters)

A total of six drawings were made, corresponding to eccentricities of 0, 0.2, 0.4, 0.6, 0.8 and 1.0. Since population studies have shown that the most frequently occurring central corneal radius is 7.8 mm, it was this radius that was used as the anterior apical radius for each of the six drawings.(see page 10).

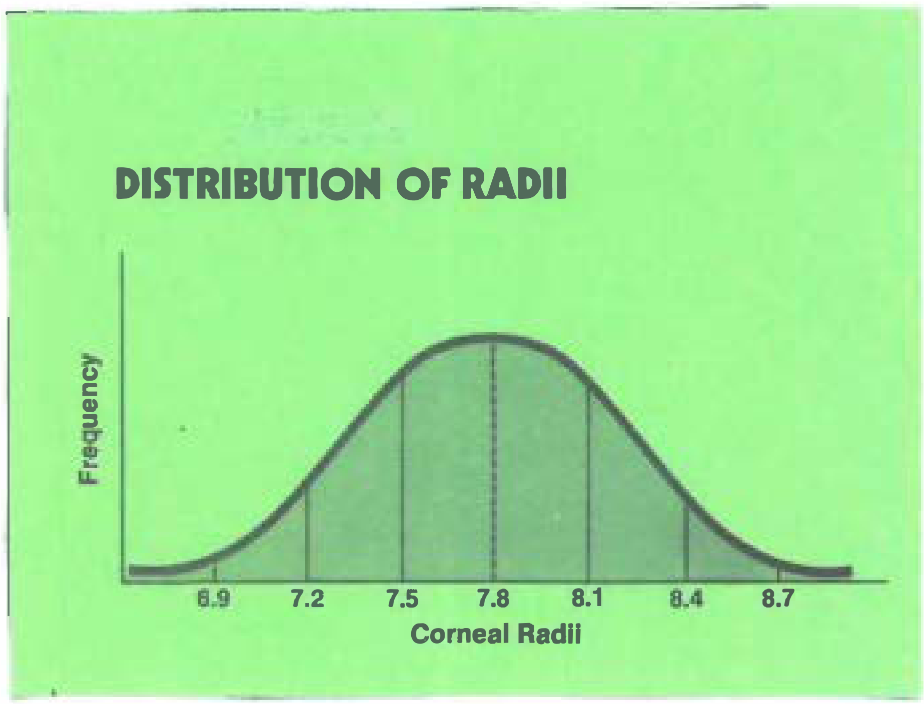
The drawings were photographically reduced to their proper size and the curves on the photographs were translated onto .030 " Vinyln plastic. When the curves were cut out of the plastic, the templates thus produced were sent to a lens manufacturer*.

In order that the anterior surface be large enough to accommodate a B & L SOFLENS^{tm}, the chord diameter of of the lenses was approximately 14.0 mm.

The powers of the anterior aspheric lenses were verified while immersed in sterile saline solution inside a specially designed cell to be used with a Nikon projection vertometer. By using a millimeter scale, it was possible to extrapolate the power measurement to the nearest .01 Diopter. A series of five measurements were made on each lens and the average value was calculated.

Three B&L SOFLENS^{tm} were selected on the basis of Touch's Best- Fit Band Chart for the 7.8 mm anterior apical radius. The Best- Fit lenses that are defined by the 7.8 mm central radius were a -0.50 J, a -2.50 F

*Ahlf's Enterprises of Sebastopol, California



©Courtesy of Bausch and Lomb

and a -4.50 B, as shown on page 12.

Each of the SOFLENS^{tm} was verified in the saline solution cell, concave side up (to minimize flexure). Again, five measurements were taken and averaged.

Each SOFLENS^{tm} was placed on each anterior aspheric lens and five measurements of the resultant power were taken while the entire lens system was immersed in the saline solution. An average value of the five measurements was utilized to calculate the supplemental power effect for each of the eighteen SOFLENS^{tm}/ corneal analog combinations.

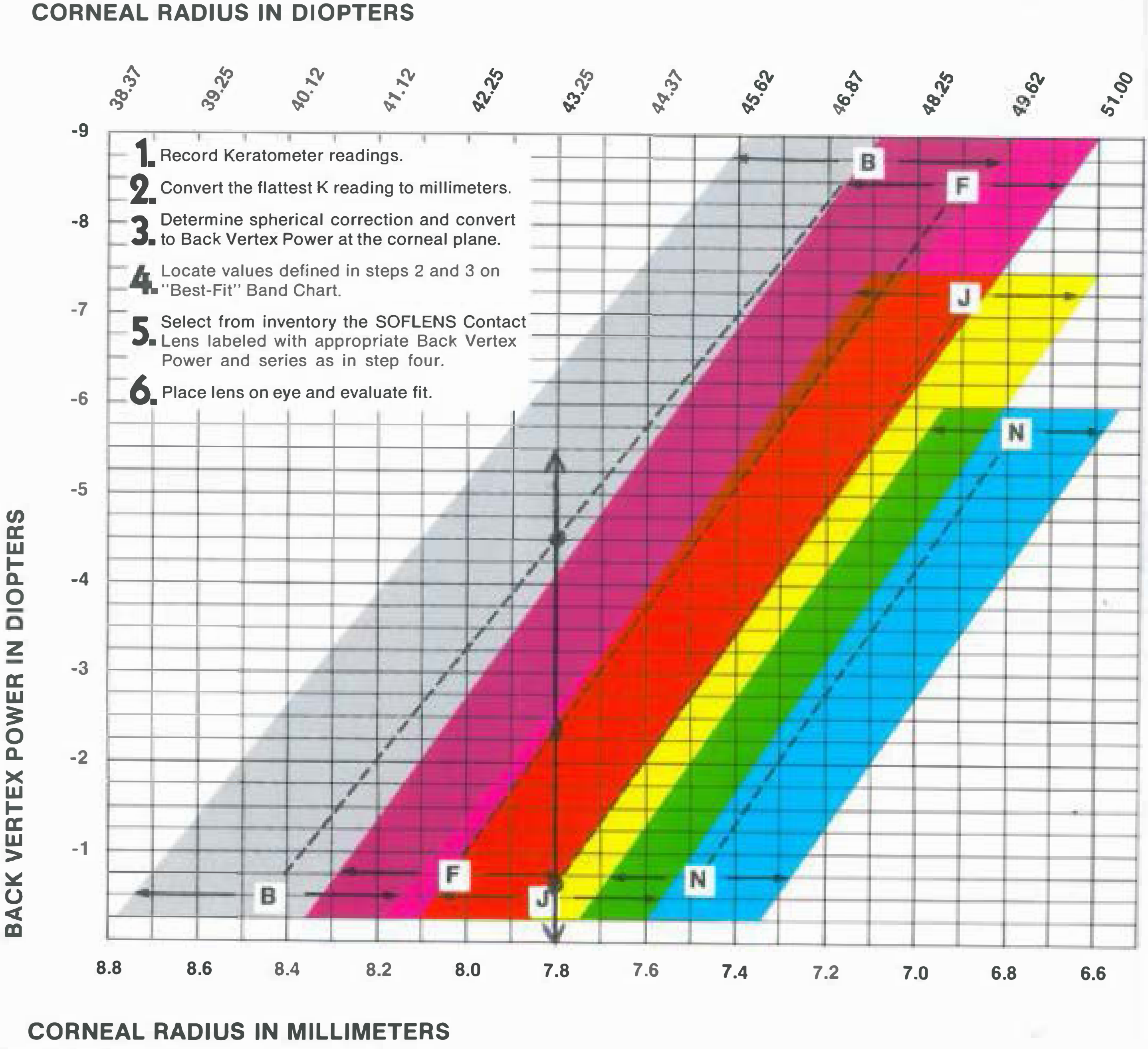
Ten students from the Pacific University College of Optometry were selected for participation in the second portion of the study. Selection was based on a keratometric (B & L) screening process. The subjects were to have no more than .25 Diopters of corneal astigmatism (since our corneal analogs had no astigmatic surfaces, this prerequisite was desireable).

A B & L Keratometer was calibrated and each subject's "K" readings were taken and recorded. The patients' best subjective refraction was recorded and the corneal eccentricities were measured with the Wesley/ Jessen Photoelectric Keratoscope (PEK).

For each cornea, a SOFLENS^{tm} was chosen on the basis of the keratometer findings and the Best- Fit Band Chart, with regard to only corneal radius, so that the lenses

"Best-Fit" Band Chart

soflens®
(polymacon)
CONTACT LENS



1. Record Keratometer readings.
2. Convert the flattest K reading to millimeters.
3. Determine spherical correction and convert to Back Vertex Power at the corneal plane.
4. Locate values defined in steps 2 and 3 on "Best-Fit" Band Chart.
5. Select from inventory the SOFLENS Contact Lens labeled with appropriate Back Vertex Power and series as in step four.
6. Place lens on eye and evaluate fit.

*Courtesy of Bausch and Lomb

were chosen from the intersection of the radius line and the Best- Fit line. The correct refracting power of the SOFLENS^{tm} for each eye was not a criterion for the fit, as it was desireable to assure the Best- Fit base curve/ corneal relationship.

After a twenty minute adaptation period, the best subjective sphero- cylindrical refraction was taken and recorded.

III. Data

The raw data from the first portion of the study is represented in the tables on pages 14 and 15.

Table 1 shows, for each lens eccentricity, the power of the anterior aspheric lens alone and the power of each of the hard lens/ SOFLENS^{tm} combinations.

Table 2 shows the measurements of the SOFLENS^{tm} alone, concave side up, in the saline solution.

Table 3 uses the data from table 1 to describe the power attributed to the SOFLENS^{tm} (power of the combination of the lenses minus the power of the analog alone).
Table 3 also shows the supplemental power effect of the SOFLENS^{tm}, which is calculated by the difference between the SOFLENS^{tm} powers listed in Table 2 and the power attributed to the SOFLENS^{tm} as shown in Table 3. The difference has been multiplied by 4.3 to convert the dioptric

ECCENTRICITY		POWER	-0.50 J	-2.50 F	-4.50 B
0.0		-0.57	-0.81	-2.28	-2.84
		-0.55	-0.75	-2.16	-2.81
		-0.45	-0.79	-2.25	-2.75
		-0.52	-0.75	-2.12	-2.81
		-0.55	-0.81	-2.30	-2.91
	$\overline{x}$ =	-0.53	-0.78	-2.22	-2.82
0.2		-2.29	-2.56	-3.06	-3.70
		-2.31	-2.62	-3.01	-3.67
		-2.35	-2.56	-3.06	-3.67
		-2.30	-2.56	-3.03	-3.62
		-2.33	-2.53	-3.04	-3.62
	$\overline{x}$ =	-2.32	-2.57	-3.04	-3.66
0.4		-1.85	-2.48	-2.59	-3.50
		-1.80	-2.38	-2.61	-3.45
		-1.84	-2.37	-2.70	-3.55
		-1.75	-2.47	-2.60	-3.48
		-1.87	-2.45	-2.75	-3.45
	$\overline{x}$	-1.82	-2.43	-2.67	-3.40
0.6		-1.18	-1.70	-2.04	-2.52
		-1.12	-1.62	-2.02	-2.50
		-1.20	-1.68	-2.01	-2.56
		-1.25	-1.62	-2.09	-2.62
		-1.19	-1.69	-2.08	-2.60
	$\overline{x}$	-1.19	-1.66	-2.05	-2.56
0.8		-2.00	-2.31	-2.94	-3.44
		-2.12	-2.31	-3.02	-3.52
		-2.10	-2.35	-2.95	-3.37
		-2.04	-2.23	-2.97	-3.37
		-2.02	-2.33	-2.97	-3.30
	$\overline{x}$	-2.07	-2.30	-2.97	-3.40
1.0		-0.37	-0.87	-1.12	-1.84
		-0.41	-0.70	-1.11	-2.02
		-0.54	-0.86	-1.23	-2.00
		-0.55	-0.73	-1.21	-1.87
		-0.50	-0.75	-1.22	-1.87
	$\overline{x}$	-0.47	-0.78	-1.18	-1.92

Table 1

POWER IN SALINE

	-0.50 J	-2.50 F	-4.50 B
	-0.41	-0.83	-1.41
	-0.41	-0.87	-1.46
	-0.41	-0.83	-1.41
	-0.37	-0.86	-1.46
	-0.36	-0.89	-1.43
$\bar{x}$	-0.39	-0.86	-1.43

Table 2

	-0.50 J			-2.50 F			-4.50 B		
ECC	PWR ATTR. SOFLENS	DIFF.	SUPPL. PWR EFFECT	PWR ATTR. SOFLENS	DIFF.	SUPPL. PWR EFFECT	PWR ATTR. SOFLENS	DIFF.	SUPPL. PWR EFFECT
0.0	-0.25	+0.14	+0.60	-1.69	-0.83	-3.57	-2.29	-0.86	-3.70
0.2	-0.25	+0.14	+0.60	-0.72	+0.14	+0.60	-1.34	+0.09	+0.39
0.4	-0.61	-0.22	-0.95	-0.85	+0.01	+0.04	-1.66	-0.23	-0.99
0.6	-0.47	-0.08	-0.34	-0.86	0.00	0.00	-1.37	+0.06	+0.26
0.8	-0.23	+0.16	+0.69	-0.90	-0.04	-0.17	-1.33	+0.10	+0.43
1.0	-0.31	+0.08	+0.86	-0.71	+0.15	+0.64	-1.45	-0.02	-0.09

Table 3

power in saline to the dioptric power in air. The 4.3 conversion factor is derived on page 17.

The series of graphs on page 18 represent the power attributed to the SOFLENS^{tm} from the data in Table 3. The red line on each graph represents the verified power the SOFLENS^{tm} in saline solution.

The graph of the supplemental power effect Vs. lens eccentricity is shown on page 19. The data represented in this graph comes from Table 3.

The raw data from the second portion of the study is shown on page 20. The keratometer readings, the refractive errors, the SOFLENS^{tm} used and the over refraction values are tabulated for each subject.(Table 5).

Table 6 describes the corneal eccentricity taken by the PEK and the supplemental power effect, for the "vertical" and "horizontal" corneal meridians. "Vertical" was defined as any meridian between 45 and 135 degrees.(there were no measurements taken in the 45/ 135 meridians, so the remainder of the readings were classified as "horizontal").

The meridians used to calculate the supplemental power effect evolved from the meridians that were used by the PEK system to analyze each cornea. In each of the two principle corneal meridians (as determined by the PEK) the refractive error was determined. This was done by utilizing the formula: $F' = F_{tot\ cyl} \text{ X } \sin^2 \theta$, where F' is

Soflens™ (Anterior Surface)

Soflens™ in Saline Solution

$n_{\text{soflens}} = 1.43$

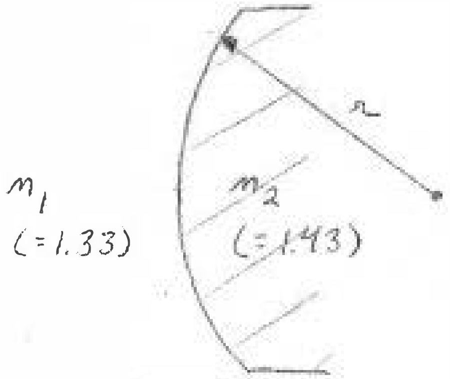
$n_{\text{saline sol'n}} = 1.3347$
at 20°C (or approx. 1.33)

Soflens™ in Air

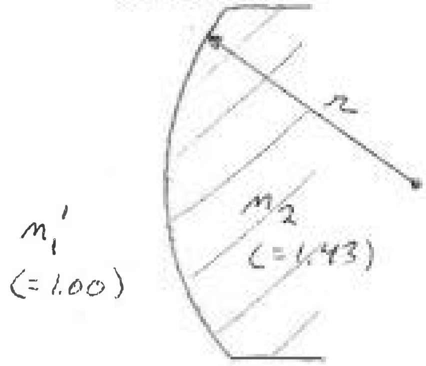
$n_{\text{soflens}} = 1.43$

$n_{\text{Air}} = 1.00$

①



②



① $\rho = \dfrac{\Delta n}{r} = \dfrac{n_2 - n_1}{r}$

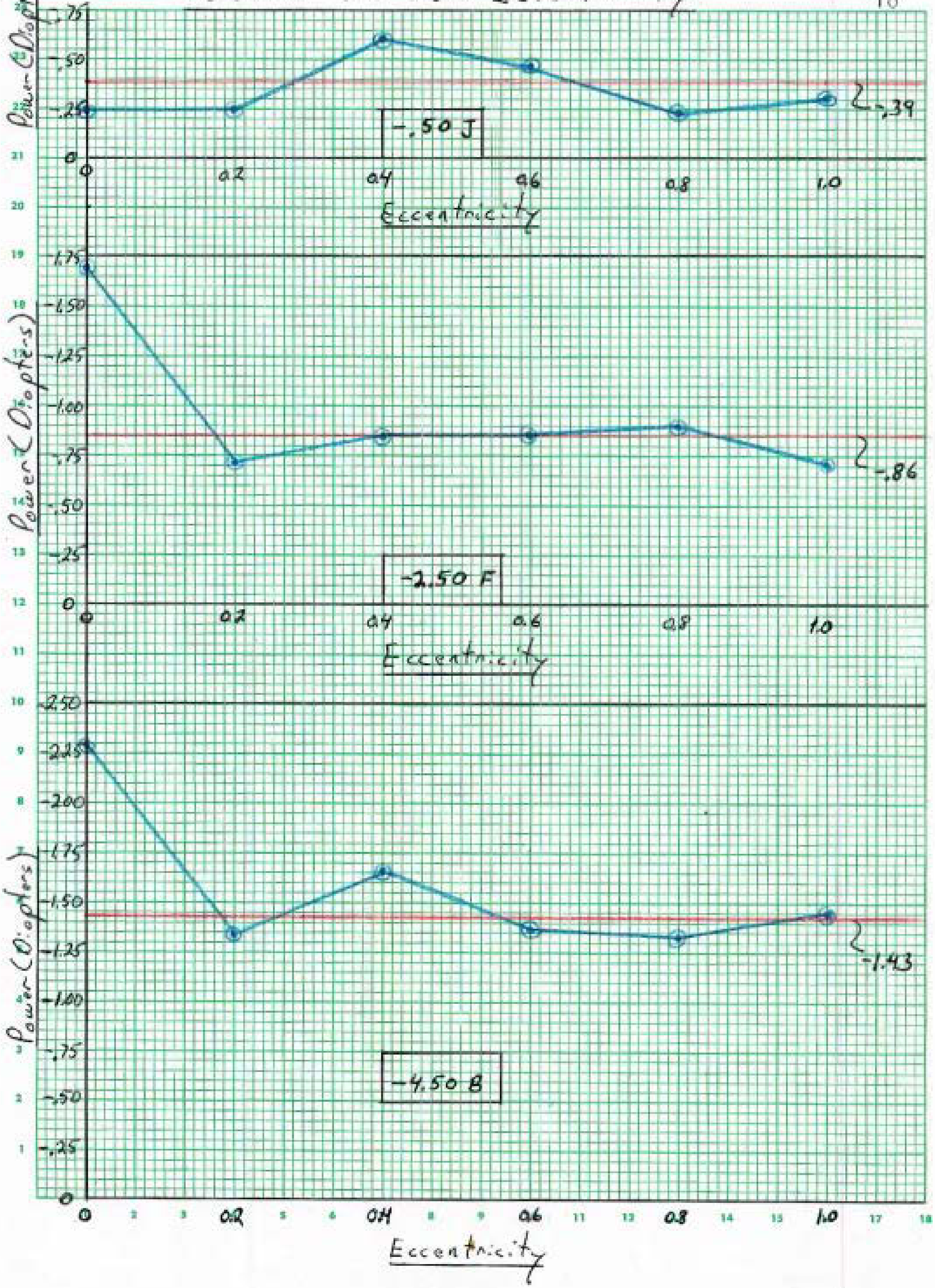
② $\rho' = \dfrac{\Delta n'}{r} = \dfrac{n_2 - n_1'}{r}$

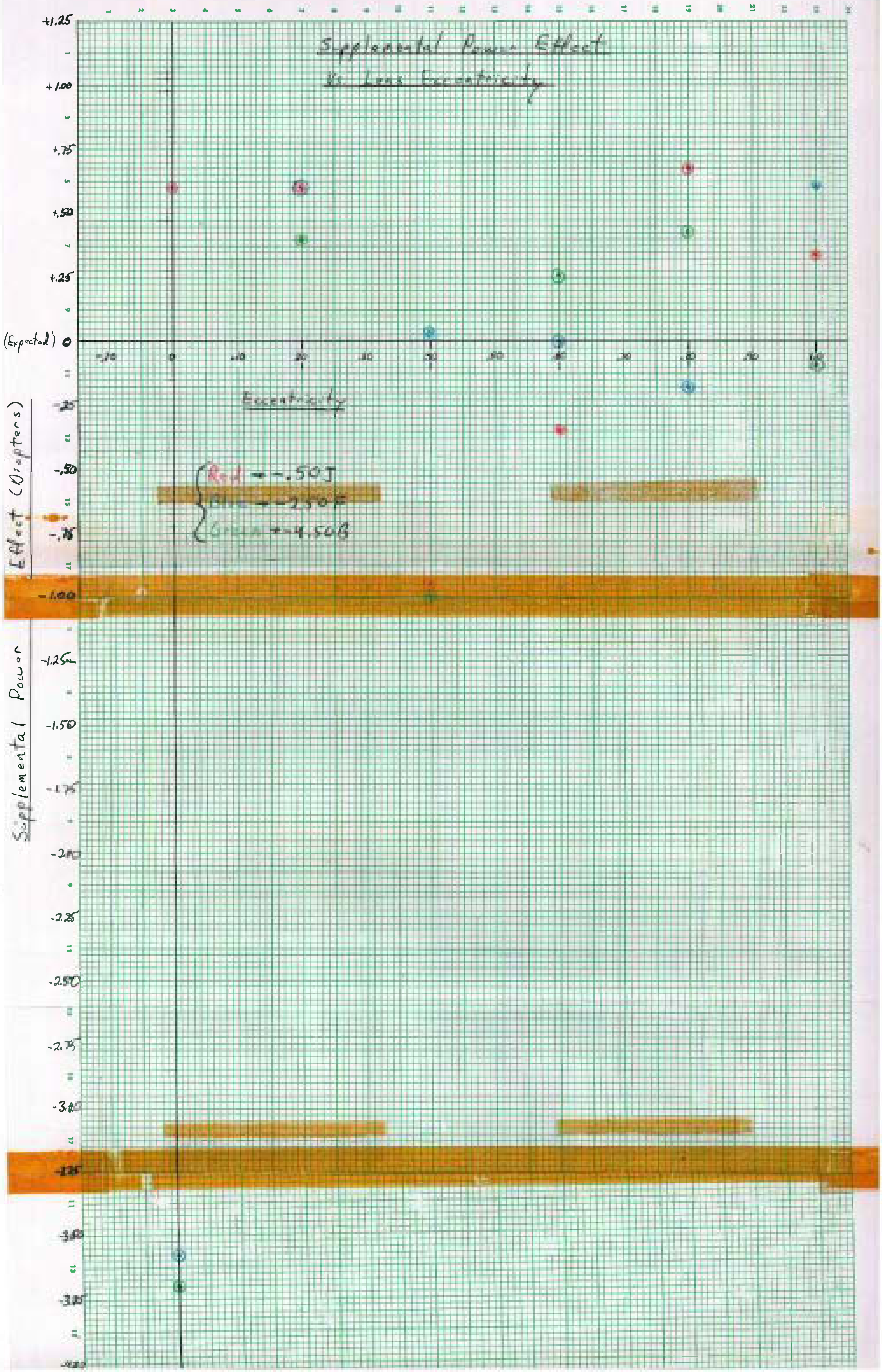
$$\rho'/\rho = \frac{n_2 - n_1'}{r} \div \frac{n_2 - n_1}{r} = \frac{n_2 - n_1'}{r} \times \frac{r}{n_2 - n_1}$$

$$\rho'/\rho = \frac{n_2 - n_1'}{n_2 - n_1} \qquad \begin{cases} n_1 = 1.33 \\ n_1' = 1.00 \\ n_2 = 1.43 \end{cases}$$

$$\therefore \rho'/\rho = \frac{1.43 - 1.00}{1.43 - 1.33} = \frac{.43}{.10} = 4.3$$

Power Attributed to Soflens^tm in Saline Solution Vs. Lens Eccentricity




Supplemental Power Effect
vs. Lens Eccentricity

		B.P.	B.F.	S.H.
"K" Readings	OD	42.12/42.12@90	44.50/44.50@90	45.00/45.12@90
	OS	42.37/42.25@90	44.75/44.75@90	45.00/45.25@90
Refractive Error	OD	+0.50-0.25x90	-2.00 sph	-2.00-0.25x90
	OS	+0.50-0.25x90	-2.50 sph	-2.00-0.25x90
SOFLENS^{tm}	OD	-3.25 B	-2.25 J	-4.50 F
	OS	-1.25 F	-2.50 J	-2.75 J
Over Refraction	OD	+3.37-0.25x135	+0.62-0.25x75	+2.50-0.25x60
	OS	+1.50-0.25x60	+0.50 sph	+1.50-0.25x125

		M.R.	T.S.	J.D.
"K" Readings	OD	42.00/42.12@90	41.50/41.37@90	41.50/41.37@90
	OS	41.87/42.12@90	41.25/41.25@90	41.50/41.62@90
Refractive Error	OD	+0.50-0.50x90	-5.50 sph	-3.25-1.00x95
	OS	+0.50-0.50x90	-5.25 sph	-3.25-0.50x95
SOFLENS^{tm}	OD	-3.25 B	-5.00 B	-4.00 B
	OS	-3.00 B	-5.00 B	-3.75 B
Over Refraction	OD	+5.00-0.25x75	0.00-0.25x60	+0.50 sph
	OS	+3.75-0.50x90	+0.25-0.25x90	+0.75-0.50x30

		P.F.	B.M.	L.H.
"K" Readings	OD	43.87/44.00@62	43.12/43.37@90	43.00/42.87@90
	OS	44.00/44.00@60	42.87/43.12@87	43.25/43.00@90
Refractive Error	OD	-1.75-0.50x180	-3.75 sph	-4.00 sph
	OS	-1.00 sph	-3.75 sph	-3.75 sph
SOFLENS^{tm}	OD	-1.50 J	-2.25 F	-4.00 B
	OS	-1.50 J	-1.75 F	-4.00 B
Over refraction	OD	-0.25-0.75x105	+1.50 sph	-0.25 sph
	OS	+0.25-0.25x130	+2.00 sph	+0.25 sph

		P.E.
"K" Readings	OD	43.75/44.00@90
	OS	44.12/44.37@90
Refractive Error	OD	-1.75 sph
	OS	-1.75 sph
SOFLENS^{tm}	OD	-1.75 J
	OS	-1.75 J
Over Refraction	OD	-0.25-0.50x100
	OS	0.00-0.50x90

Table 5

	VERTICAL		HORIZONTAL	
Subject	Eccentricity	Supplemental Power Effect	Eccentricity	Supplemental Power Effect
S.H.	0.60	-0.04	0.52	+0.09
	0.44	+0.65	0.44	+0.85
M.R.	0.76	+1.25	0.33	+0.25
	0.60	+1.51	0.43	+0.25
B.P.	0.55	-0.53	0.50	-0.23
	0.44	-0.16	0.48	-0.34
B.F.	0.59	+0.33	0.55	+0.17
	0.55	+0.50	0.56	+0.50
B.M.	0.51	0.00	0.56	0.00
	0.40	0.00	0.31	0.00
T.S.	0.48	+0.35	0.44	+0.40
	0.22	+0.48	0.45	+0.27
P.F.	0.42	+0.48	0.37	-0.27
	0.46	-0.73	0.32	-0.48
P.E.	0.62	-0.54	0.55	-0.46
	0.66	-0.16	0.62	-0.34
L.H.	-0.26	-0.25	0.50	-0.25
	-0.27	0.00	0.60	0.00
J.D.	0.26	-0.12	0.43	+0.63
	0.41	-0.19	0.40	+0.69

Table 6

the cylinder power of any meridian; $F_{tot\ cyl}$ is the total power of the cylinder; and θ is the angle between the axis (of the refractive error cylinder) and the meridian in question.

When the SOFLENS^{tm} is placed on the eye, it is possible to predict the power of the over- refraction in each meridian. These "predicted values" are shown on Table 7, page 23. The difference between the "predicted" and the actual over- refraction values in each meridian represent the supplemental power effect, which was listed in Table 6, page 21.(the method of determining the over-refraction value in each meridian was the same as the determination of the refractive error in each meridian).

The relationship between the corneal eccentricity and the supplemental power effect is shown on the graph on page 24.

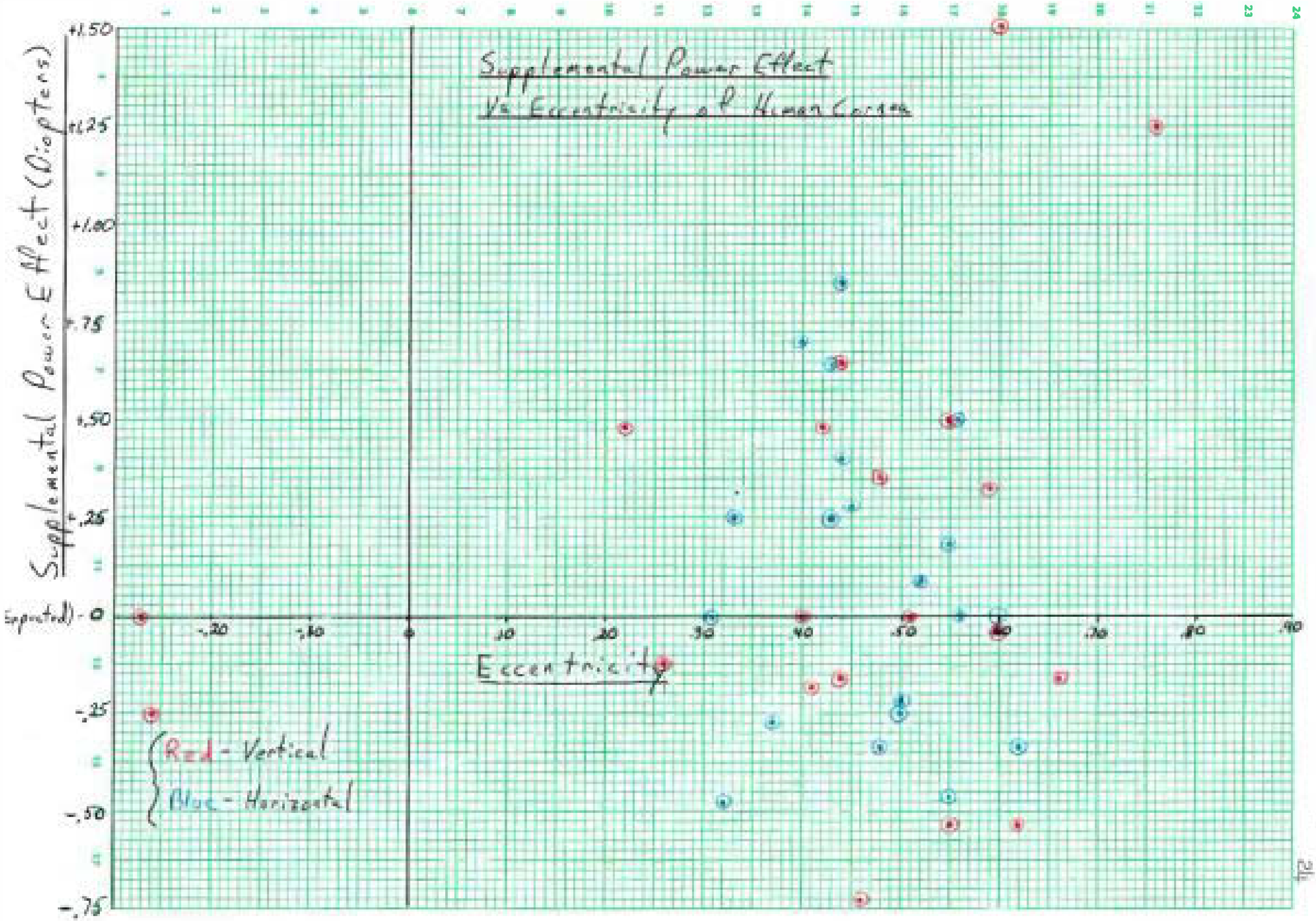
IV. Discussion

Using the data plotted in the graph on page 19, coefficients of correlation were calculated for the relationship between lens eccentricity and supplemental power effect. A coefficient of correlation was calculated for each of the SOFLENS^{tm} alone, and for the composite of all the data points.

The coefficient of correlation (r) for the -0.50 J lens was -0.034. For the -2.50 F, r = +0.631. For the

SUBJECT		MERIDIAN	REFRACTIVE ERROR	EXPECTED	ACTUAL
S.H.	OD	100	-2.01	+2.49	+2.45
		10	-2.24	+2.26	+2.35
	OS	85	-2.00	+0.75	+1.40
		175	-2.25	+0.50	+1.35
M.R.	OD	85	+0.50	+3.75	+5.00
		175	0.00	+3.25	+4.76
	OS	90	+0.50	+3.50	+3.75
		180	0.00	+3.00	+3.25
B.P.	OD	50	+0.40	+3.65	+3.12
		140	+0.35	+3.60	+3.37
	OS	50	+0.40	+1.65	+1.49
		140	+0.35	+1.60	+1.26
B.F.	OD	50	-2.00	+0.25	+0.58
		140	-2.00	+0.25	+0.42
	OS	105	-2.50	0.00	+0.50
		15	-2.50	0.00	+0.50
B.M.	OD	120	-3.75	+1.50	+1.50
		30	-3.75	+1.50	+1.50
	OS	105	-3.75	+2.00	+2.00
		15	-3.75	+2.00	+2.00
T.S.	OD	110	-5.50	-0.50	-0.15
		20	-5.50	-0.50	-0.10
	OS	105	-5.25	-0.25	+0.23
		15	-5.25	-0.25	+0.02
P.F.	OD	95	-2.25	-0.75	-0.27
		05	-1.75	-0.25	-0.98
	OS	115	-1.00	+0.50	+0.23
		25	-1.00	+0.50	+0.02
P.E.	OD	50	-1.75	0.00	-0.54
		140	-1.75	0.00	-0.46
	OS	125	-1.75	0.00	-0.16
		35	-1.75	0.00	-0.34
L.H.	OD	70	-4.00	0.00	-0.25
		160	-4.00	0.00	-0.25
	OS	90	-3.75	+0.25	+0.25
		180	-3.75	+0.25	+0.25
J.D.	OD	115	-3.37	+0.62	+0.50
		25	-4.13	-0.13	+0.50
	OS	100	-3.25	+0.50	+0.31
		10	-3.75	0.00	+0.69

Table 7



Supplemental Power Effect Vs Eccentricity of Human Cornea

-4.50 B, r = +0.649. For the composite of all data points, r = +0.479.

A t- test of significance was run for each of the correlation coefficients. In each instance, the correlation coefficients were shown to be insignificant at the .95 confidence level.

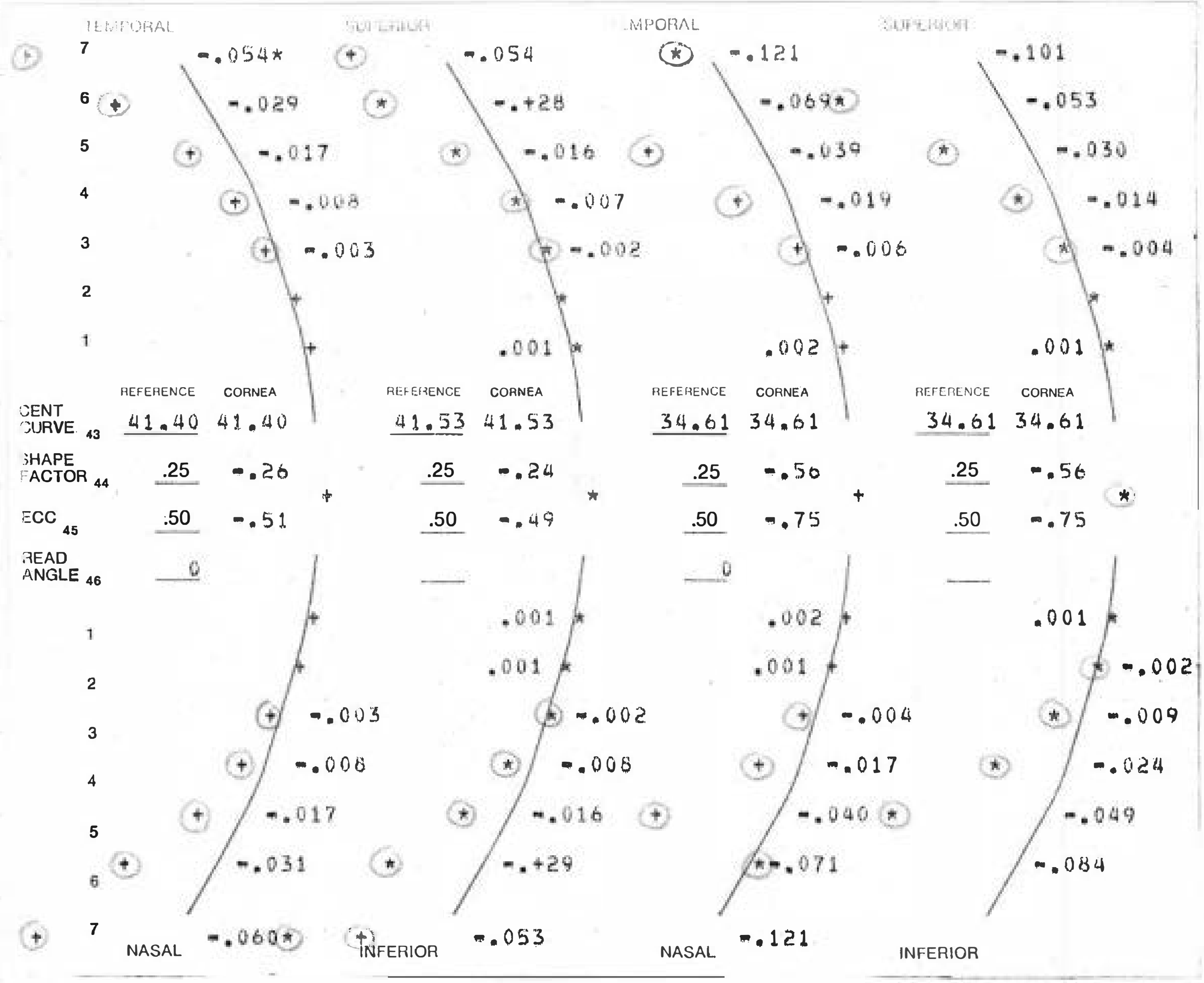
On the basis of these statistics, it can be said that the null hypothesis has been upheld, that is, there is no apparent relationship between lens eccentricity and the supplemental power effect.

There may be several reasons for this lack of significance. It was stated previously that there are no manufacturers of anterior aspheric lenses suitable for this study. For this reason, there was considerable difficulty in securing such lenses. The six lenses that were used in this study were not as precise in their construction as was desired. The lenses were sent to Dr. Malcolm Bibby at the Wesley/ Jessen Visual Data Center for analysis with one of the most highly calibrated PEK systems in existence.

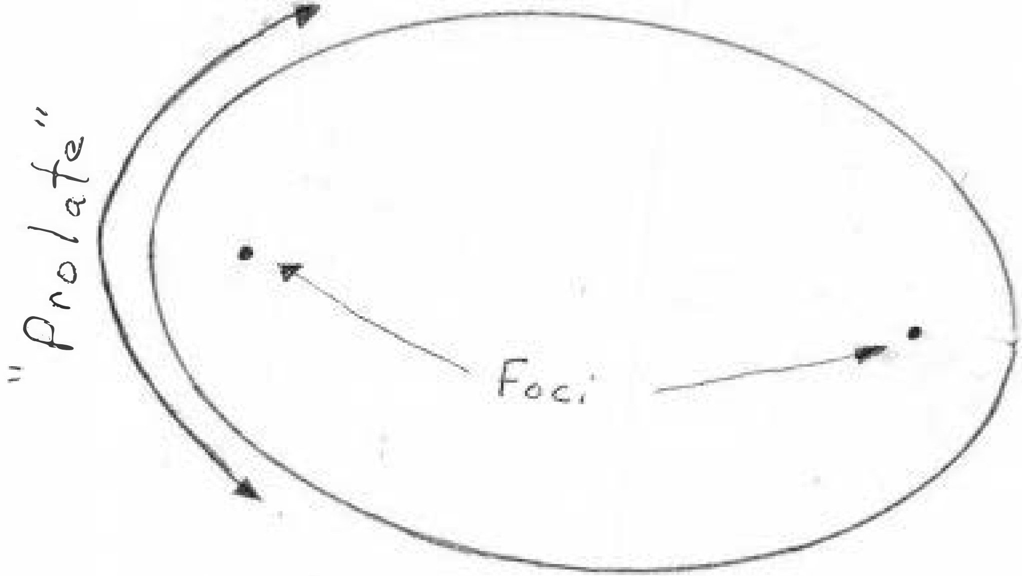
The PEK analyses established the fact that the lenses were not manufactured in accordance to the mathematical design. The computer analyses, however, measured the surface curvatures in the far periphery of the lenses. These peripheral areas, far beyond the "optical zone" of the lenses, were "rounded off" by the manufacturer, during the polishing process. As can be seen in the surface analysis on page 27, several of the points plotted against the reference curve have negative values (these points have been circled in red). This represents a "steepening" in the peripheral areas of the lens. The Wesley/ Jessen system plots a best fit curve to the locus of points represented in the analysis, and from this curve evolves the assigned eccentricity value. Since the periphery of the lenses had been "rounded off", the "resultant eccentricity" was skewed toward negative values. A negative eccentricity value implies that the aspheric surfaces were oblate, as opposed to the customary prolate (peripheral flattening) surfaces. The diagrams on page 28 serve to illustrate the distinction between an "oblate" and a "prolate" aspheric surface (ellipses were diagrammed in this instance).

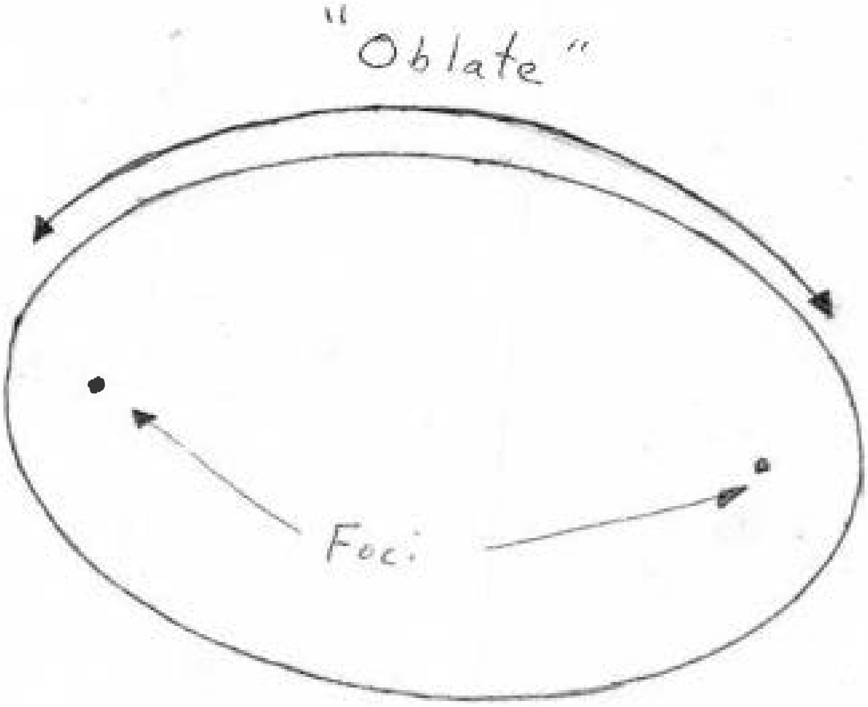
Since the peripheral steepening contaminated the eccentricity values, the Wesley/ Jessen eccentricity values were disregarded. Due to the fact that the lenses did match the templates in the central area where the optical measurements were taken, the design eccentricities were utilized in the study.

Another contaminant of the study resulted from the fact that the Best- Fit SOFLENS^{tm} were selected on the assumption that a keratometric reading on the surfaces would have yielded a 7.8 mm radius of curvature. Since



*Courtesy of Wesley/ Jessen


"Prolate"
Foci


"Oblate"
Foci

the keratometer must measure a 3 mm chord diameter area on a surface, the actual radius would be somewhat longer, due to the flattening of the surface from the actual apex of the lens.

Another possibility might be that the vertometer may not be sensitive enough to detect the small power changes that could result from a change in eccentricity.

Due to lens induced aberrations and the dehydration time of the SOFLENS^{tm}, it was necessary to utilize the specially designed saline bath for the power measurements. A 6 mm aperture, which approximates the pupil size in dim illumination, also helped to eliminate peripheral optical aberrations.

It was not possible to measure the anterior radii of the SOFLENS^{tm}/ analog system due to the dehydration induced optical aberrations.

It should be noted that there was no "limbal structure" present on the analog lenses, so any resultant effect from such a structure would not be evident.

As was done for the anterior aspheric lens portion of this study, coefficients of correlation were calculated for the eccentricity/ supplemental power effect relationship for the human cornea portion of the study. The data represented in the graph on page 24 was used for calculation of the r values.

The coefficient of correlation (r) for the vertical meridian was +0.239. For the horizontal meridian findings, r = -0.147. For the combined vertical/ horizontal data, r = +0.151.

As done previously, a t- test of significance was run for each of the correlation coefficients. In each instance, the correlation coefficients were shown to be insignificant at the .95 confidence level. Again the null hypothesis has been upheld, indicating no apparent relationship between corneal eccentricity and supplemental power effect.

A relatively large number of variables may have had a contaminating effect on the relationship between eccentricity and the supplemental power effect in this "human" portion of the study.

Kaplan, as previously noted, has labeled these variables as "unpredictable optical effects"[9]. Some of these variables might be HEMA elasticity, surface tension, resiliency of material and capillary attraction. Observations in this study implied that lid pressures and tear quantity were two of the more prominent variables.

The data was divided into vertical and horizontal components primarily to differentiate any effects of the palpebral aperture. The scatter of the data implies that there was no consistent difference between the vertical and horizontal supplemental power effects.

If Javal's rule would have been adhered to, the predicted over refraction values for the horizontal meridians would have been somewhat more minus. This would have a bearing on the horizontal supplemental power effects, theoretically, but again, the scatter of the data would suggest that it was not necessary to utilize Javal's rule. (i.e. horizontal findings were not consistently more minus).

In cases where a small amount of corneal cylinder was present, the Best- Fit SOFLENS^{tm} was selected on the basis of the flattest corneal curvature. This may have altered the data to a small extent.

Another factor that would influence the data is that the best subjective refraction and over- refraction could be measured only within ± 0.12 Diopter. This might be too insensitive a measurement to detect any small power change resultant from a change in eccentricity.

Also, the PEK analyses of the subject's corneas revealed that the eccentricity values change in the various meridians. Some unpredictable aberrations may have been induced by this corneal characteristic.

V. Conclusion

No significant clinical or experimental correlation between eccentricity and supplemental power effect has been observed in this study. It is not, at the present time, possible to make clinically useful predictions on the basis of experimental data.

There appear to be too many variables present that may affect the supplemental power effect. It is difficult to isolate eccentricity and evaluate its power effects even with the corneal analog. Further investigation as to the identification and quantification of variables is warranted.

When the manufacture of anterior aspheric lenses has been refined to the point where accurate, reproduceable and verifiable surfaces can be generated, a more difinitive investigation may be possible.

Submitted April 17, 1976

Jon M. Dahl

Jon M. Dahl

William D. Faulkner

William D. Faulkner

VI. References

1) Kaplan, Milton, O.D., "Optical Considerations of Hydrogel Contact Lenses", *Optometry Weekly*, April 7, 1966.

2) Sarver, Morton D., et. al., "The Supplemental Power Effects of Bausch and Lomb SOFLENS^{tm} Contact Lenses", *The International Contact Lens Clinic*, Vol. 1 No. 1, Spring, 1974.

3) Bailey, I.L. and Carney, L.G., "Corneal Changes from Hydrophilic Contact Lenses", *American Journal of Optometry and Physiological Optics*, Vol. 50 No. 4, April, 1973.

4) Hill, J.M., "Diurnal Variations in Keratometric Readings with HEMA Lenses", *American Journal of Optometry and Physiological Optics*, Vol. 51 No. 1, January, 1974.

5) Touch, Alan J., "The Lens- Cornea Relationship in Soflens", *Contacto*, January, 1975.

6) Sarver, Morton D., et. al., "Corneal Curvature and Supplemental Power Effect of the Bausch and Lomb SOFLENS^{tm} Contact Lens", *American Journal of Optometry and Physiological Optics*, Vol. 52 No. 7, July, 1975.

7) Mandell, Robert B., *Contact Lens Practice* (Springfield Ill.: Charles C. Thomas, Publisher, 1974), p. 215.

8) *Ibid.*, p. 214.

9) Kaplan, Milton, O.D., "Optical Considerations of Hydrogel Contact Lenses", *Optometry Weekly*, April 7, 1966.

(Supplementary)

1) Filderman, Irving P. and White, Paul F., *Contact Lens Practice and Patient Management* (Philadelphia: Chilton Book Company, 1969).

2) Spinell, Michael G., *A Clinical Guide to Hydrophilic Contact Lenses* (Philadelphia: Pennsylvania College of Optometry, 1975).

VII. Acknowledgments

We would like to express our thanks to the following:

1) Bausch and Lomb SOFLENS^{tm} Division, Rochester, New York
2) Beta Sigma Kappa International Optometry Honor Fraternity
3) The Oregon Optometric Association
4) John J. Ahlf of Ahlf's Enterprises, Sebastopol, California
5) Dr. Ramendra Bhattacharya, Professor of Mathematics, Pacific University
6) Dr. Malcolm Bibby, Wesley/ Jessen Inc., Chicago, Illinois
7) Dr. Colin Pitblado, Associate Professor & Chairman, Psychology, Pacific University
8) Dr. Don West, Professor of Optometry, Pacific University
9) Dr. Robert Yolton, Director of Research, Associate Professor of Psychophysiology, Pacific University
10) Dr. Niles Roth, Associate Professor of Physiological Optics and Optometry, Pacific University