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Abstract

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A STUDY COMPARING TWO METHODS OF PREDICTING THE SUBJECTIVE CYLINDER THROUGH CONTACT LENSES WITH THE MEASURED VALUE OF THE SUBJECTIVE CYLINDER

Presented to the faculty of
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by

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INTRODUCTION

Spherical contact lenses often can not be fit satisfactorially for one or more of the following reasons:[1]

1. Subjective cylinder through the spherical contact lenses of sufficient magnitude to reduce VA or cause other symptoms
2. Undesirable lens-cornea relationship
3. Poor centering of the lense

One of the possible methods presently being used clinically to cope with these problem cases is the prescribing of contact lenses with toric inside surfaces and lenses with a toric surface both inside and outside (bitoric). To use these types of lenses satisfactorily, the practioneer must understand the optics involved between the contact lens, lacrimal lens and cornea.

This study deals with the optical considerations of toric base curve lenses and the predictability of measurable cylinder through toric base lenses.

When a contact lens with a toric inside curve and a spherical front surface is fitted to a cornea, astigmatism is induced because of different indices (keratometer 1.3375), (contact lens 1.49), and (cornea 1.376).[2]

The Keratometer uses an assumed index of 1.3375. The cylinder power of a toric base curve lens measured on a lensmeter is 1.45x the cylinder power as measured on a keratometer.[3] (index of plastic 1.49)

1.490-1.000/1.3375-1.000=1.45

The difference in index of refraction between the front surface of the cornea and the back surface of the lacrimal layer, based on Gullstrand's schematic eye, will create a residual astigmatism amounting to about 12% of the keratometric reading, (corneal index 1.376) 1.376-1.000/1.3375-1.000=1.12. We used 10%[4] in our study rather than 12% for simplicity of calculation.

Because of the inconsistency of terminology in this area, it would be well to define the terms as used in this paper.

1. Residual Astigmatism[5]- the difference between corneal and total astigmatism.
2. Physiological Astigmatism[5]- astigmatism of approximately .50D found in the normal eye when the cornea is spherical or when the corneal astigmatism is neutralized.
3. Instrument Astigmia[6]- that amount of astigmia as measured by the ophthalmometer at the optic cap based upon an index of refraction of 1.3375.
4. Precorneal Fluid Induced Astigmia[6]- that amount of astigmia as measured by the ophthalmometer at the optic cap based upon an index of refraction difference of .04 (cornea 1.376 minus 1.336 precorneal fluid) at the interface of precorneal fluid-cornea.
5. Plastic Induced Astigmia[6]- that amount of astigmia resulting from a toric concavity in situ based upon an index of refraction difference of -.154 (1.336 precorneal fluid minus

1.490 plastic) at the interface of plastic-precorneal fluid.

6. Resultant Cylinder - cylinder measured when the cornea is fit with a spherical contact lens (this is a combination of the residual and the precorneal induced cylinder).

7. Resultant Modified Cylinder - the resultant cylinder, defined above, is modified by subtraction or addition of the precorneal induced cylinder. The four possible modifications of the resultant cylinder are listed below:

   a. Resultant cylinder plus the precorneal induced when resultant cylinder is minus cylinder axis 90 and corneal cylinder is minus cylinder axis 180.

   b. Resultant cylinder plus precorneal induced when resultant cylinder is minus cylinder axis 180 and corneal cylinder is minus cylinder axis 90.

   c. Resultant cylinder minus precorneal induced when resultant cylinder is minus cylinder axis 90 and corneal cylinder is minus cylinder axis 90.

   d. Resultant cylinder minus precorneal induced when resultant cylinder is minus cylinder axis 180 and corneal cylinder is minus cylinder axis 180.

PURPOSE OF INVESTIGATION

This study is a continuation of the investigation made by Rod D. Porter and Robert T. Whissiel in 1964, "A Method of Predicting the Subjective Cylinder, when the Cylinder has been induced by various Toric Base Contact Lenses."[7]

We were interested in adding to their results the correlation found when the selection of patients was extended to include non-wearers of contact lenses at the time of the study.

Our purpose was to increase n for the Pearson correlation coefficient obtained in the Porter and Whissiel thesis.

PROCEDURE

1. Habitual contact lens wearers were selected from Pacific University College of Optometry case files who showed two diopters or more corneal toricity as measured with a Bausch and Lomb Keratometer.
2. Non-contact lens wearers who showed two diopters or more corneal toricity as measured above were selected from availability.
3. Contact lens orientation was a criteria of this study, i.e., the coincidence of the flattest corneal meridian with the flattest base toric meridian. Only those cases where the flattest meridian of the base toric lens falls within 10 degrees of the flattest corneal meridian will be used for the study of the Pearson correlation coefficient.
4. Procedure for gathering findings was as follows;
   a. Corneal measurements were taken with the Bausch and Lomb Keratometer according to standard procedure utilizing any necessary correction factors found with Wesley Jessen Contactometer.
   b. The subjective refraction was determined using the following procedures:
      1. Clock-dial cylinder taken through that amount of plus over the patient's habitual best visual acuity in order to blur a 20/40 Snellen acuity line so that only two or three letters are readable.

2. Red-green--reduction in plus until first reversal from red to green.

3. Jackson Cross Cylinder--standard flip cylinder technique using a plus or minus .50 Diopter cylinder with the target being the standard 20/40 Snellen acuity.

4. 20/40 Equalization--using alternate occlusion and/or dissociation using vertical prism.

5. Plus sphere reduced O.U. until patient reports the ability to read the 20/20 line of Snellen acuity letters.

6. Plus spheres reduced O.U. to best visual acuity.

c. The above procedure was first done without contact lenses.

d. This was repeated with a spherical contact lens with its base curve within .25D of the flattest corneal meridian.

e. Various toric base contact lenses with the flattest meridian within .25D of the flattest corneal meridian and the steepest meridian at least .75D steeper than the flattest meridian were placed on the subjects eye. As soon as the lens stopped rotating the procedure was started. Immediately after obtaining the cylinder component and before the patient blinked the orientation of the toric contact lens was determined by observing the flattest meridian of the lens and comparing this meridian to the axis notation on the Bausch and Lomb Green's Refracter.

f. The number of lenses was limited by the library of toric base contact lenses available at the Pacific University Clinic.

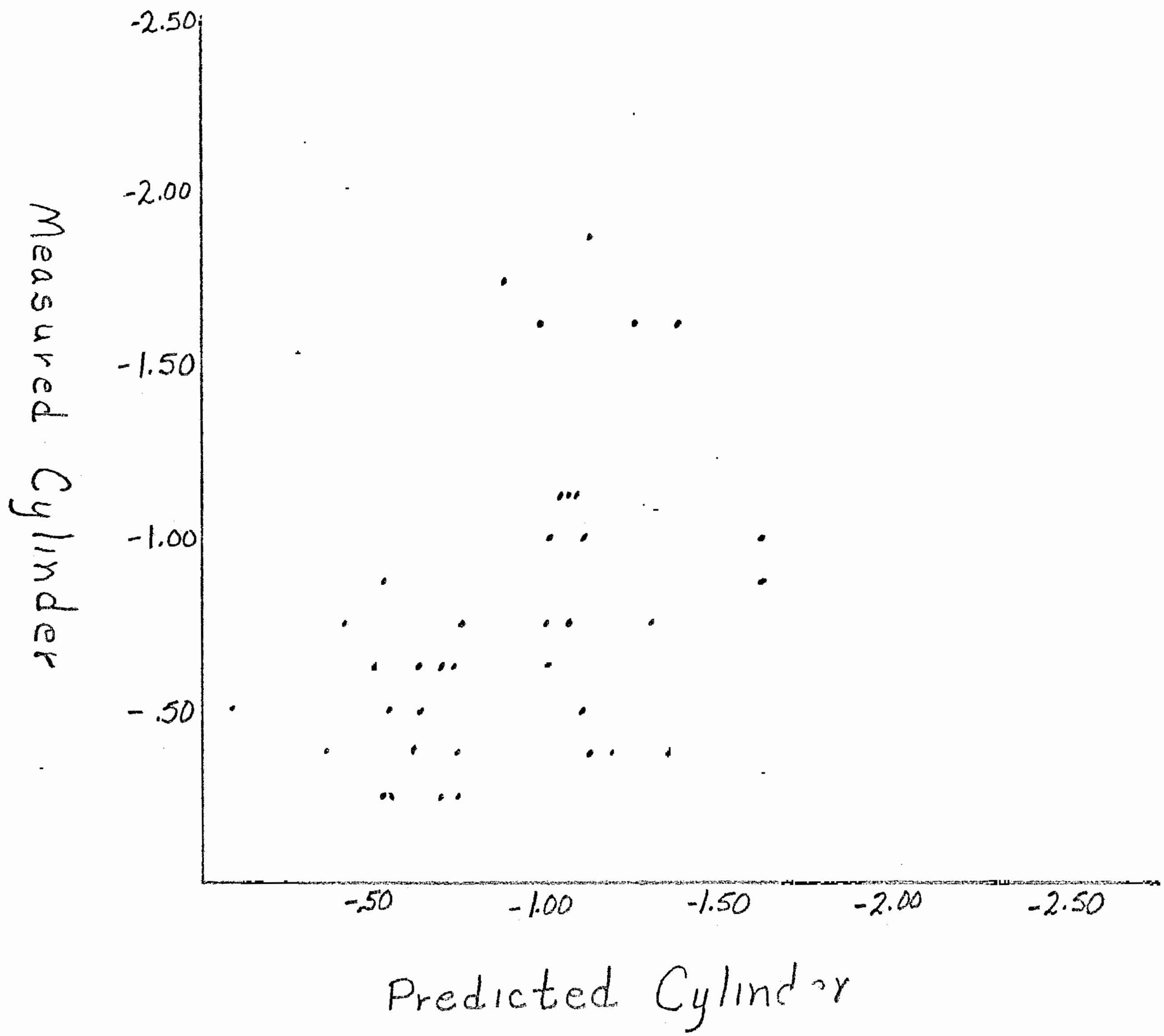
Tabulated and Calculated Data

Subject	Eye	Corneal Readings	Subject without contact lens	with sphere base contact lens	Orient *1	ΔK	*2 % of K	toric contact lense Base Curve	Predicted Residual Cylinder (Method 1)	Resultant Modified Cylinder (Method 2)	Predicted Subjective Cylinder Method 1	Measured Subjective Cylinder	Predicted Subjective Cylinder Method 2
J.M.	OD	40.12@180=43.12@90	-3.00x178	-.12x36	170°	3.00°	42%	40.50/41.75	-.30x90	-.35X10	-.52X90	-.25x25	-1.15x93
"	"	" "	"	"	175°	"	100%	40.37/43.37	"	"	-1.35X90	-.37X23	-1.98x92
"	"	" "	"	"	2°	"	79%	39.87/42.25	"	"	-1.07X90	-1.12x70	-1.70X92
"	"	40.00@180=42.87@90	"	"	5°	2.87°	83%	"	-.16X90	-.35X10	"	-1.12x85	-1.56X90
"	"	40.00@180=43.12@90	"	"	175°	3.12°	76%	"	-.43x90	"	"	-1.12x82	-1.83x92
"	OS	40.25@180=43.87@90	-4.50x180	-.12x90	180°	3.62	38%	40.50/41.87	-.52X180	-.24X180	-.62x90	-.62X180	-.34X90
"	"	" "	"	"	2°	"	72%	40.25/42.87	"	"	-1.18x90	-.37X80	-.90x90
"	"	40.12@180=44.00@90	"	"	170°	3.88	67%	"	-.23X180	-.27X180	-1.11x90	-1.00X82	-1.15X90
G.S.	OD	41.12@180=43.75@90	-2.25x7	-.25X37	175°	2.63	67%	40.50/42.25	-1.00X70	-.20x73	-1.00X81	-.75X80	-1.75x80
"	"	" "	"	"	180°	"	62%	40.62/42.25	"	"	-.75X82	-.75x90	-1.50x76
"	"	" "	"	"	180°	"	57%	40.50/42.00	"	"	-1.00x81	-.62x90	-1.75X74
"	OS	40.50@175=43.50@85	-2.75x173	-.25x110	177°	3.00	96%	40.12/43.00	-.55x85	-.25x152	-1.29x85	-.75x97	-2.12x83
"	"	" "	"	"	165°	"	54%	40.50/42.12	"	"	-.68x85	-.25X90	-1.50x88
"	"	" "	"	"	165°	"	58%	40.25/42.00	"	"	-.74X85	"	-1.37X80
H.A.*	OD	46.37@30=49.00@120	-2.37x34	00	25°	2.63	95%	45.25/47.75	-.52X120	-.26x30	-1.11X120	-.50X120	-1.89X120
" *	"	" "	"	00	35°	"	57%	46.00/47.50	"	"	-.68X120	-.62X130	-1.46X120
" *	OS	46.25@170=49.25@80	-2.25x166	-1.00X66	160°	3.00	54%	45.62/47.25	-1.05x80	-.75X62	-.70x80	-.62X40	-1.25X91
" *	"	" "	"	"	180°	"	71%	45.37/47.50	"	"	-.09x170	-.50X40	-.62x105
.R.*	OD	43.87@170=47.62@80	-3.12x178	-.12x60	165°	3.75	60%	43.50/45.75	-1.87X51	-.37X4	-1.12x96	-.37X37	-2.37X70
" *	"	" "	"	"	175°	"	67%	43.00/45.50	"	"	-1.62x85	-1.00x42	-3.12X70
" *	OS	43.75@5=47.62@95	"	-1.25x120	10°	3.87	81%	43.25/46.37	-1.25X114	-1.00X130	-1.25X108	-1.62X115	-2.00X97
" *	"	" "	"	"	180°	"	55%	43.25/45.37	"	"	-.87X97	-1.75X115	-1.50X96
" *	"	" "	"	"	2°	"	71%	43.00/45.75	"	"	-1.12X91	-1.87X110	-1.75X90

*1 flattest toric base curve contact lens orientation
*2 percent of toric base culinder to corneal astigmatism

Subject	Eye	Corneal Readings	Subject without contact lens	with sphere base contact lens	Orient. *1	ΔK	% of K *2	toric contact lense base curve	Predicted Residual Cylinder (Method 1)	Resultant Modified Cylinder (Method 2)	Predicted Subjective Cylinder Method 1	Measured Subjective Cylinder	Predicted Subjective Cylinder Method 2
R.H.	OD	41.75@7 = 43.75@97	-1.75X13	00	10°	2.00°	44%	41.62/42.50	-.65X79	-.20X7	-.40X97	-.75X110	-1.20X88
"	"	41.87@8 = 44.00@95	-1.62X4	-.87X97	10°	2.12°	65%	41.50/42.87	-.72X95	-.66X95	-.61X95	-.37X115	-.67X95
"	"	41.75@7 = 43.75@97	-1.87X12	-.25X95	5°	2.00	68%	"	-.68X82	-.08X87	-.36X96	-.37X132	-.94X87
"	OS	41.75@170 = 43.75@80	-2.00X175	-.37X95	168°	2.00	56%	41.50/42.62	-.40X53	-.22X108	-.51X80	-.25X60	-.81X61
"	"	41.75@175 = 44.37@85	-2.12X174	-.62X95	180°	2.62	86%	41.50/43.75	-.76X85	-.39X102	-1.01X85	-1.00X90	-1.46X81
"	"	41.75@170 = 43.75@80	-1.87X172	-.62X126	175°	2.00	56%	41.50/42.62	-.33X80	-.65X135	-.50X80	-.62X120	-1.22X65
V.J.	OD	42.62@178 = 44.37@88	-1.62X178	-.62X15	5°	1.75	93%	42.37/44.00	-.30X88	-.50X12	-.74X88	-.37X5	-1.25X94
"	OS	42.62@175 = 45.12@85	-4.12X161	-1.37X150	165°	2.50	80%	42.75/44.75	-2.75X135	-1.37X145	-.62X75	pe	-1.37X115
U.H.*	OD	42.12@5 = 44.37@95	-1.75X110	-.75X75	5°	2.25	94%	41.75/43.87	-4.06X101	-.60X68	-.97X100	-1.62X95	-5.03X103
"*	OS	42.50@178 = 45.75@88	-4.00X10	-.37X35	175°	3.25	96%	42.12/45.25	-1.62X42	-.37X62	-1.37X87	-1.62X85	-1.75X68
C.H.	OD	44.00@21 = 46.25@111	-2.25X30	-.75X30	30°	2.25	72%	44.12/45.75	-.75X79	-.53X35	-.62X111	-.50X180	-1.50X103
"	OD	" "	"	"	30°	"	78%	44.37/46.12	"	"	-.75X111	pe	-1.62X103
"	OS	44.50@148 = 46.00@58	-2.00X157	-.37X150	155°	1.50	167%	44.50/47.00	-.68X3	-.22X149	-1.06X60	-.75X45	-1.20X43
R.A.	OD	43.00@20 = 44.75@110	-2.87X30	-1.00X70	10°	1.75	129%	42.25/44.50	-1.25X96	-1.00X25	-1.62X110	-.87X80	-2.00X97
"	"	" "	"	"	30°	"	71%	43.00/44.25	"	"	-.53X108	-.87X55	-1.09X86
"	OS	43.12@168 = 45.12@78	-3.37X154	-1.25X132	165°	2.00	62%	42.25/43.50	-1.75X136	-1.31X137	-.53X81	-.50X137	-.59X103

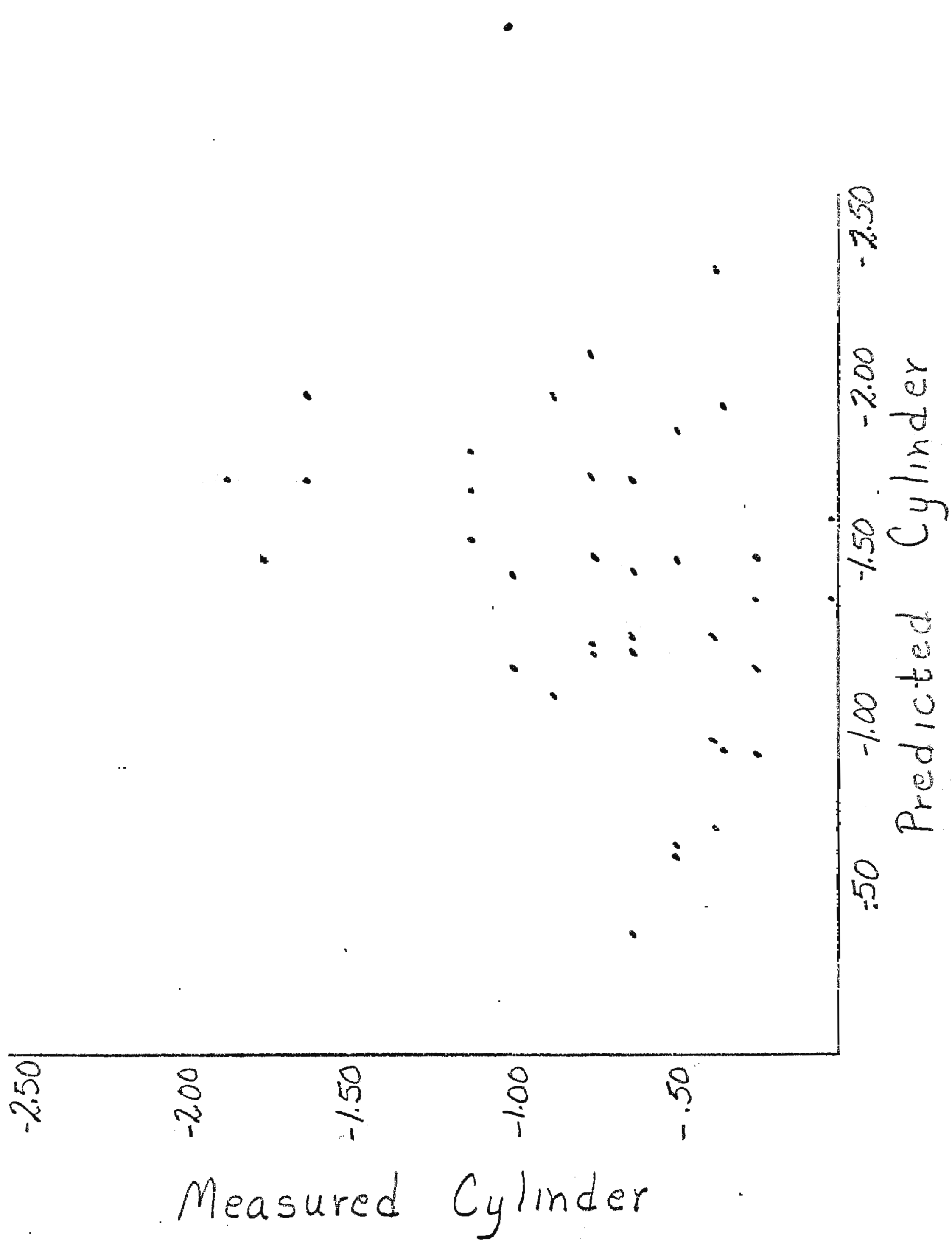
* Denotes habitual contact lense wearers



Method # 1
n = 39
r = .446
Sy.x = .316
by = .329

(503)

Method #2
n = 39
r = .432
Sy.x = .712
by = .713



RESULTS OF STATISTICAL ANALYSIS OF THE DATA

Method #1

Pearson Correlation Coefficient

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}} = .446$$

Regression Coefficient

$$b_y = \frac{\Sigma xy}{\Sigma x^2} = .329$$

Standard Error of Estimate

$$S_{y \cdot x} = \sqrt{\frac{\Sigma (y - \tilde{y})^2}{n-2}} = .316$$

Method #2

Pearson Correlation Coefficient

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}} = .432$$

Regression Coefficient

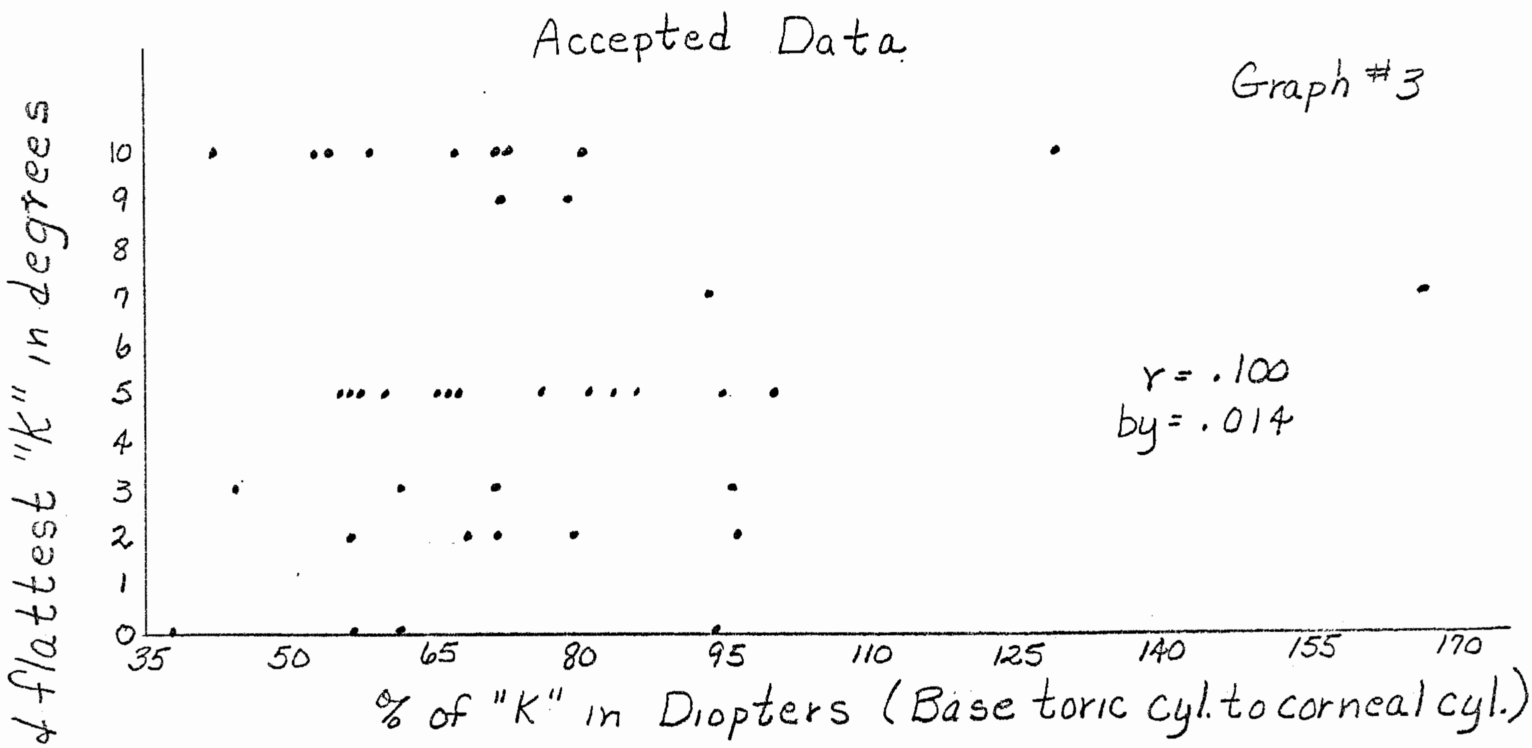
$$b_y = \frac{\Sigma xy}{\Sigma x^2} = .713$$

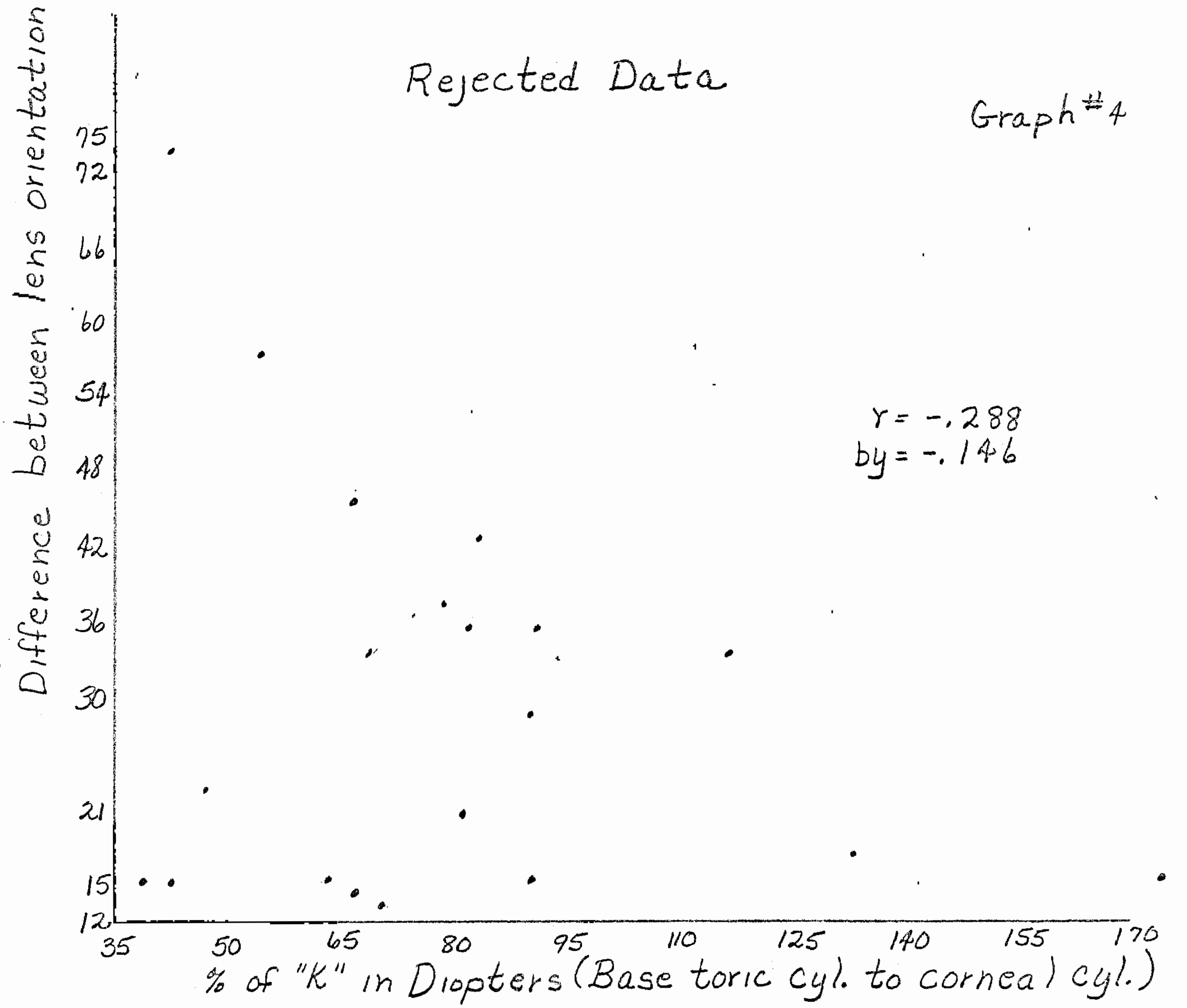
Standard Error of Estimate

$$S_{y \cdot x} = \sqrt{\frac{\Sigma (y - \tilde{y})^2}{n-2}} = .712$$

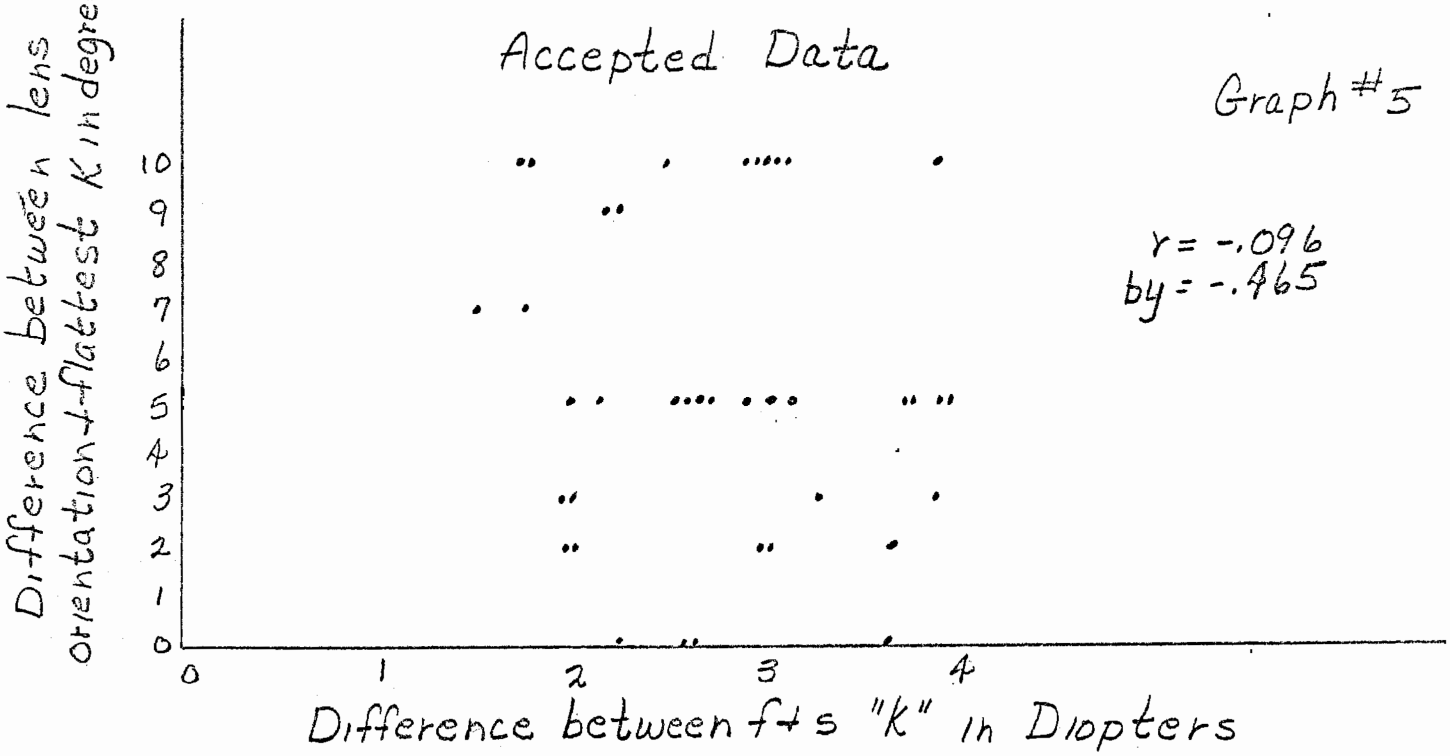
Tabulated Results

	r Pearson correlation coefficient	Sy·x	by
Method 1 Including n=39 of non-wearers and wearers of contact lense.	.446	.316	.329
Method 2 Including n=39	.432	.712	.713
Method 1 Including only habitual contact lense wearers. n=11	.382	.126	.259
Method 2 Including only habitual contact lense wearers n=11	.306	.117	.599
Including only ~~NON-wearers~~ — Method 1	.434	.292	.423
of contact lenses n=28 — Method 2	.279	.210	.375

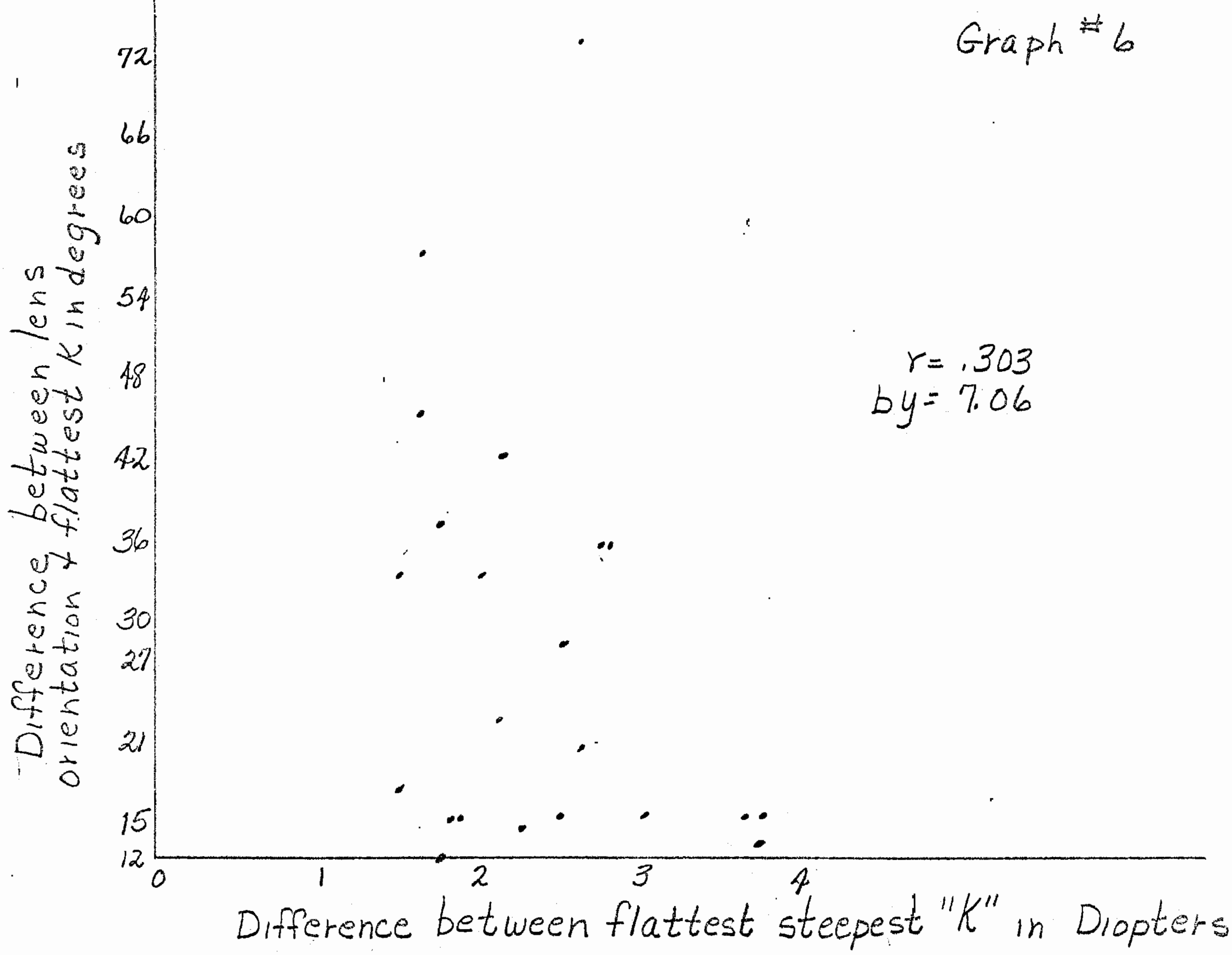

Accepted Data
Graph #3
Difference between lens orientation & flattest "K" in degrees
r = .100
by = .014
% of "K" in Diopters (Base toric cyl. to corneal cyl.)


Rejected Data
Graph #4
r = -.288
by = -.146
% of "K" in Diopters (Base toric cyl. to corneal cyl.)

Accepted Data



Rejected Data



DISCUSSION

Two methods of prediction of the cylindrical component of the refraction through each toric lens were employed. One prediction was made using the residual astigmatism and the other prediction was made using the resultant modified cylinder as defined in this paper.

Eleven subjects met the criteria of this study, three of which were contact lens wearers. Thirty-nine of sixty-one refractions through base toric lenses met the 10 degrees tolerance criterion of the experiment design. Of the thirty-nine acceptable refractions eleven were contact lens wearers, the remaining twenty-eight refractions non-contact lens wearers.

Graphical analysis method was used to determine the resultant cylinder when obliquely crossed cylinders were encountered.

Method one utilized the residual cylinder and yielded a correlation coefficient of .446 for all subjects (n=39), for non-contact lens wearers .434, and .382 for the subjects who were habitual contact lens wearers.

Method two, which utilized the resultant modified cylinder, yielded a correlation coefficient of .432 for all subjects (n=39), for non-contact lens wearers .279, and .306 for the subjects who were habitual contact lens wearers.

In the initial study of habitual contact lens wearers (n=16), Porter and Whissiel, found a correlation coefficient of .740 with a standard error of estimate of .141 for method one. For method two Porter and Whissiel found a correlation coefficient of .885 with a standard error of estimate of .122 for habitual contact lens wearers.

Possible reasons for the lower correlations are the larger n in this study, totation of the lens, different method of measuring lens orientation, measurement errors, and contact lens tilt.

Additional interesting information may be gained from a statistical study of the data on all subjects was made to determine the possible relation between errors of orientation and the following factors; differences between the flattest meridians of the corneal reading and the flattest toric base curve of the contact, the magnitude of the corneal cylinder, and the percentage of this corneal cylinder used in the several toric lenses used for each patient.

A statistical study of lens orientation (difference between the flattest corneal reading and flattest toric base curve) and percent of "K" (toric base cylinder compared to corneal astigmatism) was made. For the accepted data it was -.288. For the rejected data this means there is a correlation of -.288 for lenses to orientate more closely to the flattest corneal meridian the greater the percent of "K". The probable reason for the accepted being a positive value was that the accuracy of reading orientation was plus or minus five degrees. (As an example if the orientation were off five degrees it could have been read as zero degrees or ten degrees.)

A statistical study of lens orientation and corneal astigmatism was also made. For the accepted data the correlation was -.096, while for the rejected data it was .303. The positive value for the rejected data would indicate that for larger corneal astigmatism the difference in flattest "K" and flattest toric base curve are greater. This doesn't seem plausible and would likely not be repeatable in future studies.

SUMMARY

Two methods were used to predict the subjective cylinder when cylinder was induced by a toric base contact lens.

The prediction was then compared to the measured subjective cylinder through the base toric contact lens.

POSSIBLE SOURSES OF ERROR

1. Physical condition of the library of lenses may have been a factor where lower correlations were found since the lenses were available for use in the interm between this project and the initial study.
2. Vertex distances were not measured introducing a source of error in magnitude of cylinder.
3. Rounding off calculations to the nearest .12D may have introduced error.
4. The dotting of the flattest meridian of the Toric contact lens is a possible source of error.
5. Meriodional alignment of the cylinder was difficult to access closer than five degrees.
6. Measurement errors are inherent in studies involving subjective responses.
7. Contact lens tilt has been found to induce oblique astigmatism in range from .001D to .241D with a mean value of .071D.[8]

SUGGESTIONS FOR FUTURE STUDIES

1. A time study of subjects wearing toric lense would be beneficial to see if the measured values would correlate with predicted values more closely after full wear than before wearing contact lenses.

2. A study of the reliability of the measurements should be made using the same lenses on different days to see if the results would vary or be stable.

3. A study of the validity of the measurements should be made using the clock dial or similar test at distance for cylinder, Jackson Cross Cylinder test for astigmatism, and near cylinder test with linear marks rather than dots on the lenses to determine orientation.

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