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Abstract

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A METHOD OF PREDICTING THE SUBJECTIVE CYLINDER, WHEN THE CYLINDER HAS BEEN INDUCED BY VARIOUS TORIC BASE CONTACT LENSES

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Introduction

Spherical contact lenses can not be fit satisfactorily 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 lenses

In order to better cope with these problem cases, lenses with toric inside surfaces and lenses with a toric surface both inside and outside (bitoric) are being used. To use these types of lenses satisfactorily, the practioneer must understand the optics involved between 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), (cornea 1.376).[2]

When the astigmatism of the cornea is measured keratometrically, the measurement is based on Gullstrand's "simplified" schematic eye. Actually, the Keratometer measures radius of curvature which is then converted to diopters. The Keratometer uses an assumed index of 1.3375.

If radii of 7.5 mm. and 7.85 mm. were measured on the Keratometer, the dioptric powers of the corneal surface comparable to these radii would be 45.00 and 43.00, respectively, showing a supposed corneal astigmatism of 2.00 diopters.

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%[3] in our study rather than 12% for simplicity of calculation.

The cylinder power of a toric base curve lens measured on a lensometer is 1.45x the cylinder power as measured on a keratometer.[4] (index of plastic 1.49) 1.490-1.000/1.3375-1.000=1.45

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.

The resultant modified cylinder was determined in instances of obliquely crossed precorneal induced and resultant cylinder by lensometer neutralization of the respective components placed in a trial frame.

The amount of astigmia posterior to the cornea must be known irrespective of fitting a spherical front surface toric base curve or a bitoric lens. Three methods that have been used to arrive at this value are:

1. Comparison of total refractive status with corneal cylinder
2. Refraction of the eye with a spherical contact lens in situ
3. Using mean values of .25 D axis 90 under age 30, .50D axis 90 age 30-60 .75D axis 90 over 60[7]

During the study we used two definitions of the non corneal cylinder (cylinder posterior to the cornea), these were residual astigmia and resultant modified cylinder as defined above.

PURPOSE OF INVESTIGATION

This study is an attempt to arrive at a clinical method of predicting the subjective cylinder in a refraction, while the patient is wearing a toric base curve contact lens with a spherical front surface.

PROCEDURE

1. Patients were selected from Pacific University, College of Optometry case files on the basis of the following criteria:
   a. Patients, who were at the time of this study, wearing contact lenses, and who:
   b. Show 1.00 Diopter or more of corneal toricity as measured with a Bausch & Lomb Keratometer.
2. Procedure for gathering findings was as follows:
   a. Corneal measurements were taken with the Bausch and Lomb Keratometer according to published 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 sphere reduced O.U. to best visual acuity.

c. This was repeated with a spherical contact lens with its base curve equal to the flattest corneal meridian.

d. Various toric base contact lenses with the flattest meridian parallel to the flattest corneal meridian and the steepest meridian either parallel or some degree of curvature falling between the flattest and steepest meridians. This amount will be limited by our library of toric base contact lenses.

e. The orientation of the toric contact lens was ascertained by dotting the flattest meridian and comparing it with that found by the keratometer, having patient wear a trial frame, and noting the position of the dots on the lens in relation to the axis notation of the frame.

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 as defined in this paper as the astigmatism posterior to the cornea. (difference between cylinder in a subjective refraction and corneal cylinder) The other prediction was made using the resultant modified cylinder (defined in this paper as the astigmia posterior to the cornea).

Seven subjects were used which met our criteria as outlined. A total of 16 refractions through toric base lenses were run on these subjects.

When obliquely crossed cylinders were encountered, the components were placed in a trial frame at corresponding axis and the resultant cylinder obtained with a lensometer.

The determination of the obliquely crossed cylinders could have been made by Thompson's Formula or graphical analysis. The lensometer method was chosen for speed and convenience reasons.

#The toric lens induced more cylinder than the patient subjectively required. The lens that corrects the excessive cylinder induced is modified by the modified resultant cylinder to arrive at a predicted cylinder in the refraction with the toric base curve contact lens.

A few examples are given below:

Only the cylindrical portion of each refraction was considered, because the spherical portion had the same effect in all meridians and did not affect our predictions).

SUBJECT: G.S.

P: -2.25 × 180

K_c = 41.37 @ 180 & 44.00 @ 90

BI-SPHERICAL CONTACT LENS P: -.50 × 180

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	K_c CYL.	CONT. LENS CYL. × 1.45	PREDICTED RESIDUAL CYL.
90	-44.00	+41.37				-2.25 × 180 SUBJ. % C.L.
			-.26	-2.62	.00	+2.88 × 180 INDUCED
180	-41.37	+41.37				+ .63 × 180 RESIDUAL
			.00			

The findings needed to arrive at residual were instrument astigmia times .10, to arrive at the total corneal cylinder. The difference was the residual used in one method to predict the refraction through a toric base curve contact lens.

A toric base lens was handled as shown below using the residual found above in making one prediction.

TORIC BASE CONTACT LENS 41.50/45.25 P: -2.25 × 91

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL × 1.45	METHOD #1 — #
90	-44.00	+45.25				-2.25 × 180 SUBJ. % C.L.
			-.26	+1.25	-5.43	-4.56 × 180 INDUCED
180	-41.37	+41.50				+ 2.31 × 180
				+.12		+ .63 × 180 RESIDUAL
						-1.69 × 90 PREDICTED
						-2.25 × 91 MEASURED

*The toric lens induced more cylinder than the patient subjectively required. The lens that corrects the excessive cylinder induced is then modified by the residual to arrive at a predicted cylinder was modified by the factor 1.45, because of the difference in indices of the plastic 1.490 and the lacrimal lens 1.336

Example #2 using modified resultant cylinder in prediction

SUBJECT : G.S.

P = -2.25 × 180

K_c = 41.37 @ 180 & 44.00 @ 90

BI- SPHERICAL CONTACT LENS P = -.50 × 180

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	$(\Delta K_c)(.1)$	K_c CYL	CONT. LENS CYL × 1.45	MODIFIED INDUCED RESULTANT CYL.
90	-44.00	+41.37				-.50 × 180 +/- SPH. C.L
			-.26	-2.62	.00	(-) -.26 × 180 $(K_c)(.1)$
180	-41.37	+41.37				-.24 × 180 MODIFIED RESULTANT
			.00			

The modified resultant cylinder is determined by the appropriate combination of resultant axis and corneal axis as was described in the definition or the term.

TORIC BASE CONTACT LENS 41.50/45.25 P = -2.25 × 91

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	$(\Delta K_c)(.1)$	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL × 1.45	METHOD #2 - #
90	-44.00	+45.25				-2.25 × 180 SUBJ. & C.L
			-.26	+1.25	-.543	(-) 4.56 × 180 INDUCED
	-41.37	+41.50				+2.31 × 180
180						(-) -.24 × 180 MOD. RESULT
				+.12		-2.55 × 90 PREDICTED
						-2.25 × 91 MEASURED

SUBJECT: G. S.

O.D. P = -2.25 x 180

K_c = 41.37 @ 180 & 44.00 @ 90

BI-SPHERICAL CONTACT LENS
P = -.50 x 180

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL. x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
90	-44.00	+41.37				-2.25 x 180 SUBJ. % C.L.	-.50 x 180 % SPH. C.L.
			-.26	-2.62	.00	(-) -2.88 x 180 INDUCED	(-) -.26 x 180 (K_c)(.1)
180	-41.37	+41.37				+ .63 x 180 RESIDUAL	-.24 x 180 MODIFIED RESULTANT
			.00				

#1 TORIC BASE CONTACT LENS

41.50 / 45.25
P = -2.25 x 91

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
90	-44.00	+45.25				-2.25 x 180 SUBJ % C.L.	-2.25 x 180 SUBJ. % C.L.
			-.26	+1.25	-5.43	(-) -4.56 x 180 INDUCED	(-) -4.56 x 180 INDUCED
180	-41.37	+41.50				+ 2.31 x 180	+ 2.31 x 180
						(+) .63 x 180 RESIDUAL	(+) .24 x 180 MOD. RESULT
				+.12		- 1.69 x 90 PREDICTED	- 2.85 x 90 PREDICTED
						-2.25 x 91 MEASURED	-2.25 x 91 MEASURED

SUBJECT: G. S

O. S. P = -2.50 x 175

K_c = 43.87 @ 85 & 40.87 @ 175

BI-SPHERICAL CONTACT LENS

P = -.25 x 159

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
85	-43.87	+40.87				-2.50x175 SUBJ. % C.L	-25 x 159 % SPH. C.L.
			-.30	-3.00	.00	⊖-3.30x175 INDUCED	⊖-.30x175 (K_c)(.1)
175	-40.87	+40.87				+.80x175 RESIDUAL	-.12 x 35 MODIFIED RESULTANT
				.00			

#2 TORIC BASE CONTACT LENS

41.12 / 44.25

P = -2.00 x 89

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
85	-43.87	+44.25				-2.50x175 SUBJ % C.L	-2.50 x175 SUBJ. % C.L.
			-.30	+.37	-4.53	⊖-4.46 x175 INDUCED	⊖-4.46 x175 INDUCED
175	-40.87	+41.12				- 1.96 x 85	- 1.96 x 85
				+.25		⊖+ 80x175 RESIDUAL	⊖- .12 x 35 MOD. RESULT.
						-1.16 x 85 PREDICTED	-1.87x90 PREDICTED
						-2.00 x 89 MEASURED	-2.00 x 89 MEASURED

SUBJECT: L.R

O.D. P = -2.75 x 4

K_c = 44.50 @168 c/w 47.50 @78

BI-SPHERICAL CONTACT LENS

P = -.75 x 70

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
78	-47.50	+44.50	-.30	-3.00	.00	-2.75 x 4 SUBJ. % C.L ⊖ -3.30 x 168 INDUCED -1.50 x 47 RESIDUAL	-.75 x 70 % SPH. C.L ⊖ -.30 x 168 (K_c)(.1) -1.00 x 70 MODIFIED RESULTANT
168	-44.50	+44.50					

#3 TORIC BASE CONTACT LENS
44.25 / 46.75

P = -.75 x 70

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
78	-47.50	+46.75	-.30	-.75	-3.62	-2.75 x 4 SUBJ % C.L ⊖ -4.42 x 168 INDUCED -2.25 x 60 ⊖ -1.50 x 47 RESIDUAL -1.00 x 74 PREDICTED -.75 x 70 MEASURED	-2.75 x 4 SUBJ. % C.L. ⊖ -4.42 x 168 INDUCED -2.25 x 60 ⊖ -1.00 x 70 MOD. RESULT. -1.25 x 55 PREDICTED -.75 x 55 MEASURED
168	-44.50	+44.25		-.25			

#4 TORIC BASE CONTACT LENS
44.25 / 45.87

P = -1.00 x 70

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
78	-47.50	+45.87	-.30	-1.62	-2.35	-2.75 x 4 SUBJ % C.L ⊖ 4.02 x 168 INDUCED -2.00 x 57 ⊖ -1.50 x 47 RESIDUAL -.87 x 80 PREDICTED -1.00 x 70 MEASURED	-2.75 x 4 SUBJ % C.L ⊖ 4.02 x 168 INDUCED -2.00 x 57 ⊖ -1.00 x 70 MOD. RESULT -1.00 x 80 PREDICTED -1.00 x 70 MEASURED
168	-44.50	+44.25		-.25			

SUBJECT: L. R.

O.S. P = -2.75 x 175

K_c = 44.25 @ 8 °/w 47.50 @ 98

BI-SPHERICAL CONTACT LENS

P = -1.25 x 115

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
98	-47.50	+44.25	-.33	-3.25	.00	-2.75 x 175 SUBJ. °/c C.L. ⊖ -3.58 x 8 INDUCED -1.62 x 129 RESIDUAL	-1.25 x 115 °/SPH. C.L. ⊖ -.33 x 98 (K_c)(.1) -1.50 x 112 MODIFIED RESULTANT
8	-44.25	+44.25					
				.00			

#5 TORIC BASE CONTACT LENS

44.25 / 45.87

P = -.75 x 105

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
98	-47.50	+45.87	-.33	-1.62	-2.35	-2.75 x 175 SUBJ. °/c C.L. ⊖ -4.30 x 8 INDUCED -2.00 x 118 ⊖ -1.62 x 129 RESIDUAL -.50 x 105 PREDICTED -.75 x 105 MEASURED	-2.75 x 175 SUBJ. °/c C.L. ⊖ -4.30 x 8 INDUCED -2.00 x 118 ⊖ -1.80 x 112 MOD. RESULT. -.42 x 133 PREDICTED -.75 x 105 MEASURED
8	-44.25	+44.25					
				.00			

#6 TORIC BASE CONTACT LENS

44.25 / 46.75

P = -1.25 x 118

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
98	-47.50	+46.75	-.33	-.75	-3.42	-2.75 x 175 SUBJ. °/c C.L. ⊖ -4.70 x 8 INDUCED -2.50 x 116 ⊖ -1.62 x 129 RESIDUAL -1.25 x 103 PREDICTED -1.25 x 118 MEASURED	-2.75 x 175 SUBJ. °/c C.L. ⊖ -4.70 x 8 INDUCED -2.50 x 116 ⊖ -1.50 x 112 MOD. RESULT. -1.12 x 125 PREDICTED -1.25 x 125 MEASURED
8	-44.25	+44.25					
				.00			

SUBJECT: J.W.

O.D. P = -.75 x 107

K_c = 44.00 @ 170 & 45.12 @ 80

BI-SPHERICAL CONTACT LENS

P = -.75 x 107

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
80	-45.12	+44.00				-.75 x 107 SUBJ. % C.L	-.75 x 107 % SPH. C.L.
			-.11	-1.12	.00	(+) -1.23 x 170 INDUCED	(+) -.11 x 80 (K_c X .1)
170	-44.00	+44.00				-1.87 x 90 RESIDUAL	-.87 x 105 MODIFIED RESULTANT

#7 TORIC BASE CONTACT LENS

44.00 / 46.37

P = -1.50 x 65

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
80	-45.12	+46.37				-.75 x 107 SUBJ % C.L	-.75 x 107 SUBJ. % C.L.
			-.11	+1.25	-3.44	(+) -2.30 x 170 INDUCED	(+) -2.30 x 170 INDUCED
170	-44.00	+44.00				-2.50 x 82	-2.50 x 82
				.00		(+) -1.87 x 90 RESIDUAL	(+) -.87 x 105 MOD. RESULT.
						-1.00 x 60 PREDICTED	-1.50 x 86 PREDICTED
						-1.50 x 65 MEASURED	-1.50 x 65 MEASURED

SUBJECT: S.B.

O.D. P = -3.50 ×172

K_c = 40.00 @165 & 43.00 @75

BI-SPHERICAL CONTACT LENS

P = SPHERE

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL × 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
75	-43.00	+40.00				-3.50×172 SUBJ. % C.L	.00 % SPH. C.L.
			-.30	-3.00	.00	(-)-3.30×165 INDUCED	(-)-.30×165 (K_c)(.1)
	-40.00	+40.00				-.25×15 RESIDUAL	-.30×75 MODIFIED RESULTANT
165				.00			

#8 TORIC BASE CONTACT LENS

41.12 / 43.37

P = -.12×77

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL × 1.45	METHOD #1	METHOD #2
75	-43.00	+43.37				-3.50×172 SUBJ % C.L	-3.50×172 SUBJ % C.L.
			-.30	+.37	-4.72	(-)-4.31×165 INDUCED	(-)-4.31×165 INDUCED
	-40.00	+41.12				+1.25×151	+1.25×151
165				+1.12		(-)-.25×15 RESIDUAL	(-)-.30×75 MOD. RESULT.
						-.62×68 PREDICTED	-1.00×62 PREDICTED
						-.12×77 MEASURED	-.12×77 MEASURED

#9 TORIC BASE CONTACT LENS

41.12 / 44.25

P = -.75×76

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL × 1.45	METHOD #1	METHOD #2
75	-43.00	+44.25				-3.50×172 SUBJ % C.L	-3.50×172 SUBJ % C.L
			-.30	+1.25	-4.52	(-)-4.69×165 INDUCED	(-)-4.69×165 INDUCED
	-40.00	+41.				-1.50×149	-1.50×149
165				+1.12		(-)-.25×15 RESIDUAL	(-)-.30×75 MOD. RESULT
						-1.00×72 PREDICTED	-1.62×150 PREDICTED
						-.75×76 MEASURED	-.75×76 MEASURED

SUBJECT: S. B.

O.S P = -1.75 x 12

K_c = 40.62 @ 8 °/₀₀ 42.75 @ 98

BI-SPHERICAL CONTACT LENS

P = -.25 x 95

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
98	-42.75	+40.62				-1.75 x 12 SUBJ. % C.L.	-.25 x 98 % SPH. C.L.
			-.21	-2.12	.00	(+) -2.33 x 8 INDUCED	(+) -.21 x 98 (K_c X .1)
8	-40.62	+40.62				+.58 x 12 RESIDUAL	-.46 x 98 MODIFIED RESULTANT
				.00			

#10 TORIC BASE CONTACT LENS

41.12 / 44.25

P = -1.00 x 100

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
98	-42.75	+44.25				-1.75 x 12 SUBJ % C.L.	-1.75 x 12 SUBJ. % C.L.
			-.21	+1.50	-4.52	(+) -3.73 x 9 INDUCED	(+) -3.73 x 9 INDUCED
9	-40.62	+41.12				+2.25 x 180	+2.25 x 180
				+.50		(+) +.58 x 12 RESIDUAL	(+) -.46 x 98 MOD. RESULT.
						-1.40 x 112 PREDICTED	-1.75 x 90 PREDICTED
						-1.00 x 100 MEASURED	-1.00 x 100 MEASURED

#11 TORIC BASE CONTACT LENS

41.12 / 43.37

P = -.25 x 94

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
98	-42.75	+43.37				-1.75 x 12 SUBJ % C.L	-1.75 x 12 SUBJ % C.L
			-.21	+1.37 WITH 9	-3.26	(+) -2.60 x 9 INDUCED	(+) 2.60 x 9 INDUCED
8	-40.62	+41.12				-.87 x 90	-.87 x 90
				+.50		(+) +.58 x 12 RESIDUAL	(+) -.46 x 98 MOD. RESULT
						-.27 x 102 PREDICTED	-.50 x 83 PREDICTED
						-.25 x 94 MEASURED	-.25 x 94 MEASURED

SUBJECT: H. B.

O.S P = -1.25 x 180

K_c = 41.25 @ 168 & 42.75 @ 78

BI-SPHERICAL CONTACT LENS

P = -.50 x 170

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
78	-42.75	+41.25	-.15	-1.50	.00	-1.25 x 180 SUBJ. & C.L (-)-1.65 x 167 INDUCED +.50 x 115 RESIDUAL	-.50 x 170 w/SPH. C.L. (-)-.15 x 78 (K_c)(.1) -.50 x 77 MODIFIED RESULTANT
168	-41.25	+41.25		.00			

#12 TORIC BASE CONTACT LENS

41.25 / 42.50

P = -1.25 x 92

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
78	-42.75	+42.50	-.15	-.25	-1.82	-1.25 x 180 SUBJ & C.L (-)-2.22 x 167 INDUCED + 1.25 x 155 (-)-.50 x 116 RESIDUAL -1.62 x 93 PREDICTED -1.25 x 92 MEASURED	-1.25 x 180 SUBJ. & C.L. (-)-2.22 x 167 INDUCED + 1.25 x 155 (-)-.50 x 177 MOD. RESULT. -1.12 x 70 PREDICTED -1.25 x 92 MEASURED
168	-41.25	+41.25		.00			

#13 TORIC BASE CONTACT LENS

41.12 / 44.25

P = -2.00 x 106

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
78	-42.75	+44.25	-.15	+1.50	-4.53	-1.25 x 180 SUBJ. & C.L (-)-3.04 x 168 INDUCED + 1.87 x 160 (-)+.50 x 115 RESIDUAL -2.00 x 78 PREDICTED -2.00 x 106 MEASURED	-1.25 x 180 SUBJ & C.L (-)-3.04 x 168 INDUCED + 1.87 x 160 (-)-.50 x 77 MOD. RESULT -2.25 x 75 PREDICTED -2.00 x 73 MEASURED
168	-41.25	+41.12		-.12			

SUBJECT: H.B.

O.D. P = -.25 x 143

K_c = 41.50 @ 154 & 42.37 @ 65

BI-SPHERICAL CONTACT LENS

P = -.50 x 83

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
65	-42.37	+41.50				-.25 x 143 SUBJ. % C.L.	-.50 x 83 +/SPH. C.L.
			-.08	-.87	.00	⊖ -.95 x 154 INDUCED	⊖ -.08 x 155 (K_c X .1)
155	-41.50	+41.50				+.75 x 153 RESIDUAL	-.62 x 74 MODIFIED RESULTANT
				.00			

#14 TORIC BASE CONTACT LENS

41.25 / 42.50

P = -1.50 x 56

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c X .1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
65	-42.37	+42.50				-.25 x 43 SUBJ % C.L	-.25 x 43 SUBJ. % C.L.
			-.08	+.12	-1.82	⊖ -1.53 x 155 INDUCED	⊖ -1.53 x 155 INDUCED
155	-41.50	+41.25				-1.62 x 60	-1.62 x 60
				-.25		-.75 x 153 RESIDUAL	⊖ -.62 x 74 MOD. RESULT.
						-1.75 x 67 PREDICTED	-1.12 x 56 PREDICTED
						-1.50 x 56 MEASURED	-1.50 x 56 MEASURED

SUBJECT: G. N.

O.D. P = -1.75 x 28

K_c = 42.12 @ 10 c/w 44.25 @ 100

BI-SPHERICAL CONTACT LENS

P = -.50 x 180

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	K_c CYL	CONT. LENS CYL x 1.45	PREDICTED RESIDUAL CYL.	MODIFIED INDUCED RESULTANT CYL.
100	-44.25	+42.12				-1.75 x 28 SUBJ. % C.L	-.50 x 180 % SPH. C.L.
			-.21	-2.12	.00	⊖ -2.33 x 10 INDUCED	⊖ -.21 x 10 (K_c)(.1)
10	-42.12	+42.12				+1.12 x 165 RESIDUAL	-.75 x 85 MODIFIED RESULTANT
				.00			

#15 TORIC BASE CONTACT LENS

42.62/43.50

P = -.25 x 35

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
100	-44.25	+43.50				-1.75 x 28 SUBJ % C.L	-1.75 x 28 SUBJ. % C.L.
			-.21	-.75	-1.25	⊖ -2.71 x 10 INDUCED	⊖ -2.71 x 10 INDUCED
10	-42.12	+42.62				-1.25 x 84	-1.25 x 84
				+.50		⊖ +1.12 x 165 RESIDUAL	⊖ - .75 x 85 MOD. RESULT.
						-.75 x 8 PREDICTED	-.50 x 95 PREDICTED
						-.25 x 35 MEASURED	-.25 x 35 MEASURED

#16 TORIC BASE CONTACT LENS

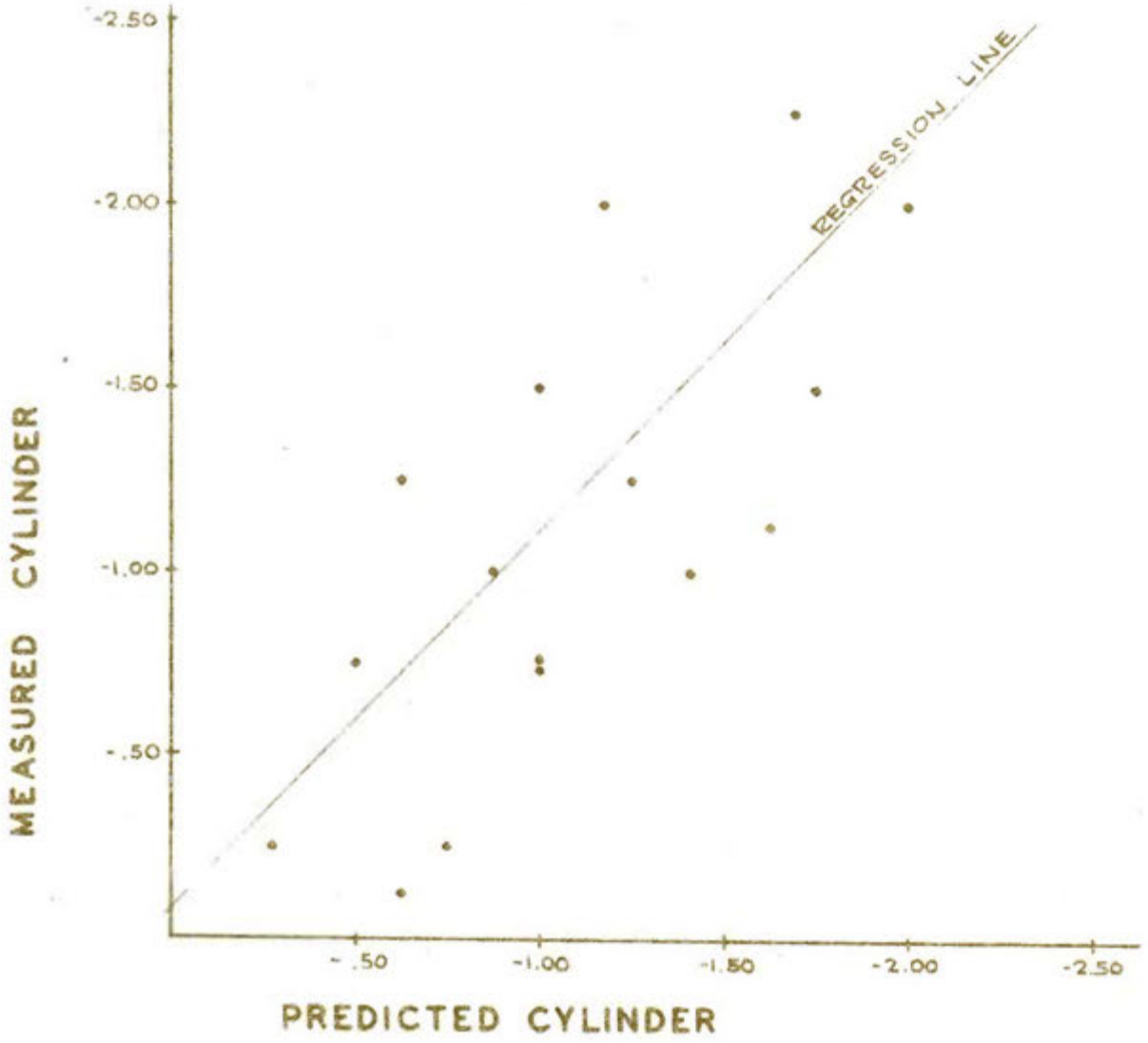
42.62/45.75

P = -1.25 x 100

CORNEAL MERIDIAN	CORNEAL CYLINDER	CONTACT LENS	(ΔK_c)(.1)	INDUCED LACRIMAL CYLINDER	CONT. LENS CYL x 1.45	METHOD #1	METHOD #2
100	-44.25	+45.25				-1.75 x 28 SUBJ. % C.L	-1.75 x 28 SUBJ % C.L
			-.21	+1.50	-4.53	⊖ -3.74 x 10 INDUCED	⊖ -3.74 x 10 INDUCED
10	-42.12	+42.62				-2.50 x 93	-2.50 x 93
				+.50		⊖ + 1.12 x 165 RESIDUAL	⊖ - .75 x 85 MOD. RESULT
						- .42 x 105 PREDICTED	- 1.75 x 96 PREDICTED
						- 1.25 x 100 MEASURED	- 1.25 x 100 MEASURED

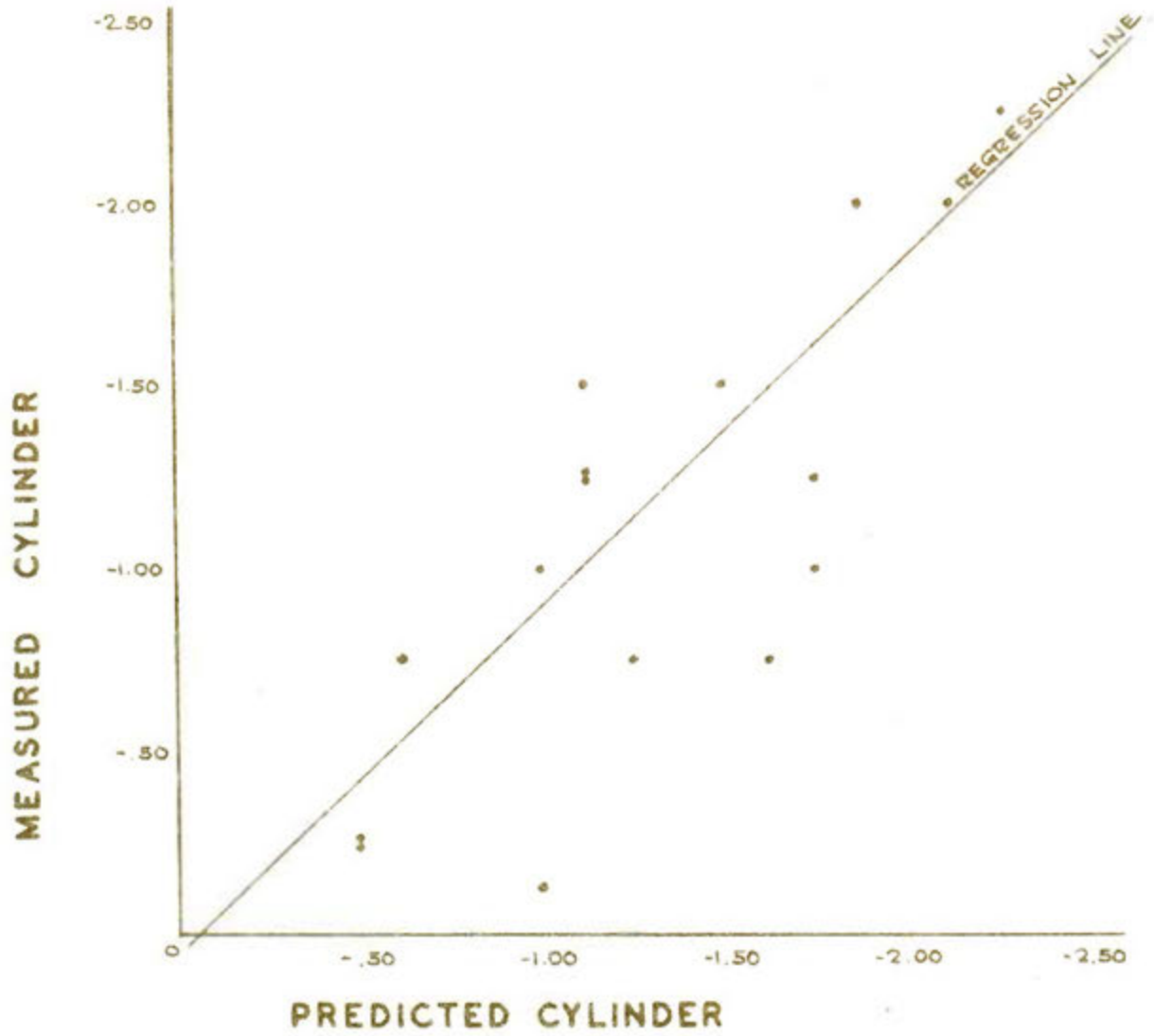
METHOD# I.

n : 16
b_y : .925
$S_{y \cdot x}$: .141
r : .740



METHOD #2

n = 16
b_{y} = .940
$S_{y \cdot x}$ = .1217
r = .885



Limitations of the study

In the study there were several limitations that could have affected the results. In those cases where the trial toric base lens did not have its flatter meridian parallel to the flatter meridian of the cornea we attemrted to parallel as close as possible.

The following could also be reasons why predicted and measured showed some difference:

1. Vertex distance - lenses in each refraction were not of sufficient magnitude to make a significant difference.
2. Warped or poorly centered lens[8] - a warped or poorly centered contact lens on the eye may induce a cylinder and a pseudo-residual astigmatism may have been detected.
3. Calculation errors - cummulative effect of rounding off to nearest .12 D.
4. Rotation of lens during the refraction - The flatter meridian of the toric lens was dotted previous to the insertion of the lens. The orientation of the lens was noted by using a trial frame to determine the coincidence of the flatter meridian of the toric lens to the flatter corneal meridian. In every case prior to the refraction, the lens oriented itself within plus of minus 3° of the corneal axis. During the refraction, however it was impossible to determine if the lens rotated and thereby giving erroneous results.

5. Measurement errors - Whatever the cause of variation, it is randomly destributed. .

Summary

A method of predicting the subjective cylinder when cylinder was induced by a toric contact lens was presented.

The predicted subjective cylinder through toric base curve lense was compared to the measured subjective cylinder through toric base lenses using two methods of prediction.

The standard error of estimate was .141 using the residual in the prediction and .1217 for the modified resultant cylinder in the prediction.

The correlation coefficient for the modified resultant cylinder method was .885 and for the other method .740.

Clinical utilization of the two methods employed in the study indicate two possibilities for fitting the toric base curve contact lenses. Each method offers the professional an approach for determining the curvature design of the front surface of the contact lens.

Method #1 extracts its data from the routine examination, is less involved and has a correlation coeficient of .740. Method #2 requires the use of a spherical contact lens, is somewhat more demanding but improves the clinical prediction with a correlation coefficient of .885.

Sixteen eyes met the criteria for the study. The error of estimate exceeded .50 Diopters of cylinder in six of the sixteen eyes using method #1 while method #2 reduced this number to three.

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