EyeSys System Analysis of RGP Flexure on Toric Corneas

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by

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ABSTRACT

It has been shown in various literature and research studies that PMMA and rigid gas permeable lenses both flex on highly toric corneas. This flexure induces astigmatism in the visual system that can be good or bad to the patients visual acuity. Lens factors that affect the amount of flexure include the lenses base curve, thickness, material, and the optic zone diameter. Ocular factors such as the amount of corneal toricity, positioning of the lens, and lid-lens interactions also affect the amount of flexure. Using articles by Pole[1-2] as a guide, we attempted to confirm the research that a change in base curve will affect flexure. We used the EyeSys Corneal Analysis System on ten subjects (19 eyes) to show that a lens fit steeper-than-K will show more flexure on a highly toric cornea than a lens fit flatter-than-K. The amount of flexure for each eye was determined from an EyeSys corneal topography map after fitting each eye with Boston II RGP lenses that were fit on-K, .10mm steeper-than-K, and .10mm flatter-than-K. A comparison was also made between the EyeSys delta-K readings and keratometer readings for each subject.

INTRODUCTION

The popularity of contact lenses in the last twenty years has revolutionized the field of optometry. As more and more people turn to contact lenses for their vision needs, optometrists and contact lens companies are always trying to improve the product they offer in order to give their patients the best possible vision. Patients with highly toric corneas who want to wear contact lenses present unique problems to eye care professionals. Patients like these who are fit with spherical rigid gas permeable lenses have been found to have a problem with the lens flexing on their eye. This flexure creates plus cylinder in the optical system and can increase or decrease the residual astigmatism for the patient, which may increase or decrease their visual acuity. In general, the flexure of a lens is an unwanted occurrence.

The effects of flexure were first documented in the 1960's and 1970's using PMMA lenses. In studies by Harris, et al,[3-8] various parameters of the lenses were changed such as thickness, diameter, and power to see what effects these changes might have on the amount of flexure of PMMA lenses. Mandell and Kimball[9] also used PMMA lenses to look at the effects of base curve changes on flexure. Because of the PMMA lenses lack of oxygen permeability, new lens materials were created that were more "eye friendly". The advent of rigid gas permeable lenses allowed transmission of oxygen through the lens, but the problems with lens flexure were not eliminated.

In the 1980's various studies were done using RGP lens materials (Polycon I, Polycon II, Paraperm, Boston II, Opticryl 60) to test the effect lens parameter changes had on flexure. Two studies by Pole, et al,[1-2] showed that base curve changes had a significant effect on flexure. As the base curve of the lens steepened the amount of flexure increased. This was confirmed in similar studies done by Herman[10]. Brown, et al,[11] studied optic zone diameter changes and its effect on flexure and residual astigmatism. It was shown that increasing the optic zone diameter results in an increase in flexure. Herman[12] also showed that lens thickness also plays a role in flexure. An increase in center thickness will make the lens more rigid and therefore reduce the amount of flexure.

In lectures by Pole[13], various factors that affect contact lens flexure were discussed. Base curve of the lens, optic zone diameter, Dk of the lens material, and center thickness all have an effect on flexure. As mentioned previously, as the base curve of a lens is made steeper, the flexure of the lens increases. The opposite holds true when base curves are made flatter. Flexure is decreased when this is done. It has also been found that the absolute amount of flexure is higher for both steep and flat base curve fits if a persons corneal toricity is higher. Optic zone diameter changes also effect flexure. As the OZD is increased, the fit of the lens is altered (making the lens fit steeper), and this creates an increase in flexure. As the OZD is decreased the lens fits flatter and the lens flexes less. Although changes in the OZD effect the amount of flexure, they may also cause unwanted optical aberrations that may bother a patient. In lectures by Pole[13] it was mentioned that, in general, lenses that have a high Dk values tend to flex more than lenses with low Dk values. Stevenson[14-15] showed in two separate studies that RGP contact lenses of higher Dk tend to flex more then lower Dk lenses in vitro. In contrast, Herman[10] found that there was no difference in flexure with different Dk value lenses in vivo. Increasing the center thickness of the lens will decrease flexure by making the lens more rigid. The center thickness of the lens must be made at least .16-.18mm thick in order to have a significant effect on flexure. Although increasing the thickness of the lens may decrease flexure, it may cause a decrease in the amount of oxygen that is transmitted through the lens and therefore may cause corneal hypoxia.

Ocular factors also affect the amount of flexure that occurs with a lens. As mentioned previously, corneal toricity plays a role in the amount of flexure. As corneal toricity increases, the amount of flexure also increases. Therefore, on highly toric corneas, a spherical RGP generally would be expected to induce more astigmatism. Pole[2] found that there was a high correlation between lens flexure and the amount of induced astigmatism. It has also been found that the central positioning of a lens will also increase flexure. Herman[11] states that an RGP lens will tend to fit more centrally on the cornea as the base curve of the lens is made steeper. Both these factors will increase the amount of flexure. Lastly, lens-lid interaction has a significant role in the amount of flexure. A lens that is positioned behind the upper lid will have against-the-rule (ATR) flexure exerted on it by the upper lid. An interpalpebral fit will have no such tension put on the lens by the upper lid. The surface tension that is created between the tear film and the and the lens also causes an RGP lens to flex. This surface tension causes with-the-rule (WTR) flexure of the lens. Hydrostatic forces are created between the tear film of the eye and the back surface of the lens, which results in negative pressure under the lens. Although ocular factors play a role in the amount a lens flexes, they are much more difficult (if not impossible) for the clinician to manipulate then lens parameters such as center thickness and base curve.

METHOD

Our study used 10 subjects (nineteen eyes) as a test group. We measured corneal toricity and RGP flexure with both the EyeSys Corneal Analysis System and a Bausch & Lomb Keratometer, but the instrument of choice for basing our data was the EyeSys. All subjects had previously had a complete eye exam at our clinic. Each eye showed corneas having with-the-rule toricity of 1.34D to 5.60D (see Graph 1.1), with a mean of 2.42D and a standard deviation of 1.04D. The axis of the steepest meridians ranged from 065* to 110*. Although most subjects were previous RGP wearers, a few were not. Table 1.1 highlights this information.

The Rigid Gas Permeable lenses used in this study were the Boston II, a PMMA and silicone copolymer called Pasifocon B, which is composed of a Methylmethacrylatedimethylitaconate Siloxanyl material. This lens has a Dk of $14.6x10^{-11}$ and a Dk/L of $9.87x10^{-9}$ (cm/sec)(mlO_2/ml mmhg). The Boston II also has a Rockwell hardness of 118 and a flexure strength of 8640 psi, which is less than a standard PMMA lens. We used a trial lens set with verified parameters of; -3.00D power, 9.0 OAD, .15mm center thickness, and an OZD of 8.0mm. The only varying parameter was the base curve, which changed to fit the individual eyes.

Prior to lens insertion, each lens was cleaned with Boston Original cleaning solution and then soaked in Boston Original soaking solution. This improved patient acceptance of the RGP lens and ensured a more accurate assessment of RGP flexure.

We used the EyeSys corneal readings of the bare cornea to find a baseline or on-K base curve (in millimeters) to fit each patient. Then we added .1mm to the on-K base curve to fit flatter-than-K, and we subtracted .1mm from the on-K base curve to fit steeper-than-K. To change a base curve .1mm radius of curvature is equivalent to .62D of curvature change. Once the lens was in place, it was allowed to settle for five minutes to minimize tears between the lens and the cornea and ensure a stable fit. At this time we took an RGP flexure measurement with the EyeSys to collect our data and measurements were taken with the Bausch & Lomb Keratometer for comparison sake.

RESULTS

Significant flexure was seen with all three types of lens fits on toric corneas. The degree of flexure, however, differed according to the specific fitting principle used. Lenses fit steeper-than-K flexed more than those fit on-K in 15 out of 19 instances. The on-K, in turn, flexed more than the flat fitting lenses in 16 eyes, with one instance of equal flexure. Only once did a lens fit flatter-than-K flex more than the corresponding steep fit.

The on-K fits all showed WTR flexure with the exception of one ATR measurement. The amount of total lens flexure averaged 0.50 ± 0.26D as measured on the 19 eyes. This resulted in an average flexure to corneal toricity relationship of 21.0 ± 10.5%. This is in contrast to the 0.66 ± 0.27D and 29.6 ± 14.5% averages seen with the steep fit. The lenses fit flatter-than-K showed considerable less flexure than either the on-K or the steep fit. The 17 WTR and 2 ATR flexures yielded an average of 0.30 ± 0.25D of total flexure and 12.8 ± 11.2% flexure of the total corneal toricity.

The amount of lens flexure also differed with the degree of corneal toricity. The three different fits were pooled, and the amount of flexure was measured on low (1.34-1.75D), medium (1.79-2.75D), and high (2.91-5.66D) corneal toricities (see Graph 1.1). There was a positive correlation between lens flexure and corneal toricity (0.34 ± 0.27D, 0.50 ± 0.31D, and 0.61 ± 0.24D for low, medium, and high respectively). There was, however, a negative correlation between the amount of corneal toricity and the percentage of lens flexure (26.7 ± 13.5%, 22.8 ± 14.4%, and 17.9 ± 7.8% for low, medium, and high respectively [see Graph 1.2]).

The last aspect studied dealt with the differences in corneal readings between the EyeSys system and the B & L Keratometer. The average toricity as measured by the EyeSys was 2.42 ± 1.04D. This was compared to the 2.95 ± 1.32D average measured by the B & L Keratometer (see Table 1.2). The EyeSys readings were 0.53 ± 0.65D lower on average than the B & L readings. The keratometer toricity measurements were higher on 14 eyes, and the EyeSys measured higher on the remaining 5 eyes.

DISCUSSION

The results of the study indicate that the amount of RGP flexure is directly influenced by the base curve fitting relationship. Boston II, 9.0 OAD lenses fit steeper than K flexed more than those fit on-K or flatter than K. Therefore, the base curve of choice for moderate to highly toric corneas should be on K or flatter than K. This criteria cannot always be followed because of frequent problems with movement and centration. Several of the flatter fits in this study showed excessive movement and poor centration. These problems are best solved using a bitoric lens design.

The data showed that although the overall lens flexure increases as the corneal toricity increases, the flexure percentage decreases in regards to the total corneal toricity. This moderate increase in flexure, therefore is not the primary reason to fit bitoric lenses on highly astigmatic corneas. The need for good fit and centration are the primary reasons for these specialty lenses.

Even thought he delta K readings were lower, on average, with the EyeSys as compared to the B & L Keratometer, there was a great deal of variability. The difficulty in getting stable lens positioning during recordings led to much of the variability in over K measurements. The delta K readings of the unaided eye also showed variability between the two different instruments.

CONCLUSION

As we have seen, as the base curve of an RGP lens is changed from flatter to steeper, the amount of flexure increases. This had been shown to be true in several previous studies. Our study, using the EyeSys system as a tool to measure flexure, confirmed the results that had been found previously. Since flexure can cause problems in obtaining the patients optimum visual acuity, it is important for clinicians to know how to change lens parameters to help reduce the flexure. Changing the base curve of the lens can be a way for a clinician to reduce or eliminate flexure as a problem.

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table 1.1

	Eyesys K- Readings	*delta K's*	*Keratometer Readings*	*delta K's*
subject one				
	R43.21@180*45.00@090	1.79@090	43.50@180*44.50@090	1.00@090
	L43.26@171*45.42@081	2.16@081	42.75@180*44.75@090	2.00@090
subject two				
	R41.51@009*44.23@099	2.72@099	41.50@011*44.75@101	3.25@101
subject three				
	R43.44@009*46.42@099	3.38@099	43.25@018*46.50@108	3.25@108
	L44.32@161*46.33@071	2.91@071	43.50@180*46.75@090	3.25@090
subject four				
	R42.66@168*45.73@078	3.03@078	42.50@172*46.25@082	3.75@082
	L42.50@003*45.42@093	2.92@093	42.50@010*46.62@100	4.12@100
subject five				
	R44.76@172*46.29@082	1.53@082	44.00@180*46.00@090	2.00@090
	L44.76@163*46.35@073	1.59@073	44.00@180*46.50@090	2.50@090
subject six				
	R42.29@020*44.34@110	2.05@110	42.25@014*44.12@104	1.87@104
	L42.08@163*43.83@073	1.75@073	39.87@170*44.12@080	4.25@080
subject seven				
	R44.00@176*46.29@096	2.29@086	44.25@180*47.25@090	3.00@090
	L43.88@173*45.42@083	1.54@083	44.25@180*46.25@090	2.00@090
subject eight				
	R41.97@165*45.54@075	3.57@075	41.75@170*45.75@080	4.00@080
	L41.41@003*47.07@093	5.66@093	41.12@009*48.00@099	6.87@099
subject nine				
	R43.60@014*45.00@104	1.40@104	43.25@037*45.5@127	2.25@127
	L43.54@154*44.88@064	1.34@064	44.00@155*45.00@065	1.00@065
subject ten				
	R43.26@017*45.54@107	2.28@107	42.50@021*45.75@111	3.25@111
	L43.15@152*45.30@062	2.15@062	42.50@172*45.75@082	3.25@082
		m=2.42		m=2.96
		SD=1.32		SD=1.32
		range= 1.34-5.66		range=1-6.87

Table 1.2

Delta K's of EYESYS vs. KERATOMETER

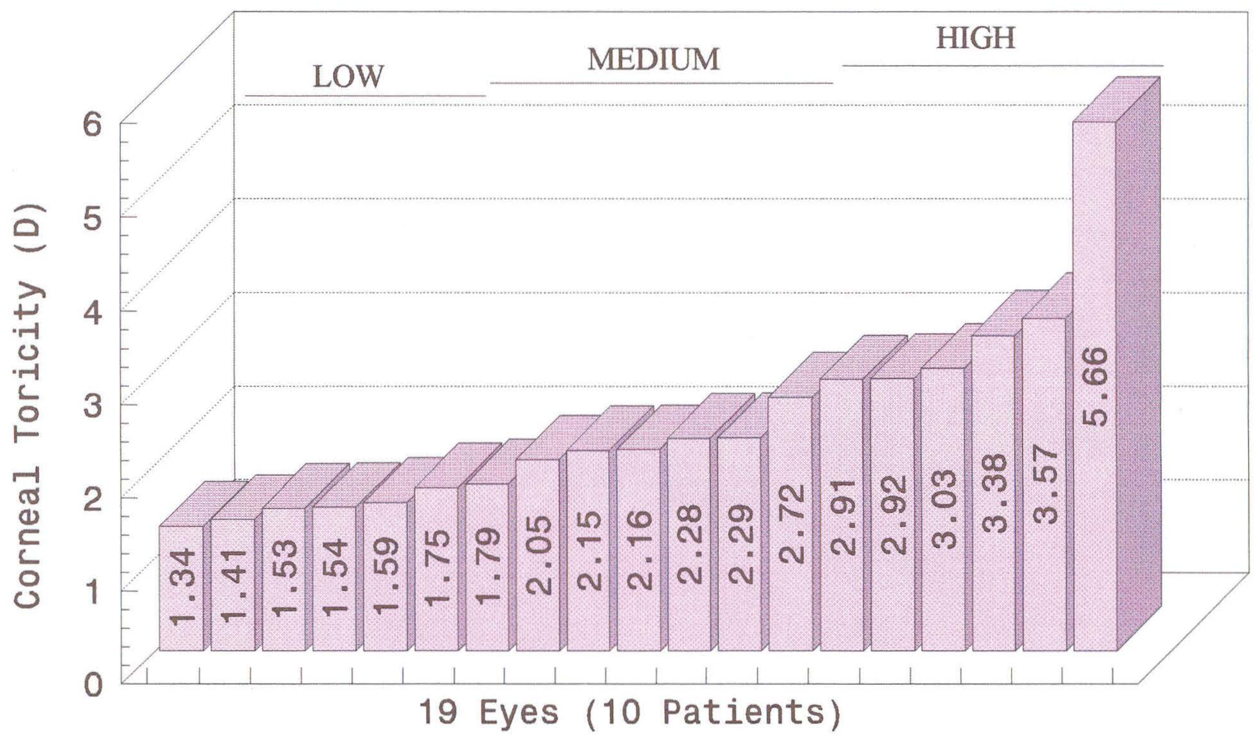
	EYESYS	*KERATOMETER*	*DIFFERENCE*
subject 1			
	R1.79	1.00	+0.79
	L2.16	2.00	+0.16
subject 2			
	R2.72	2.00	-0.53
subject 3			
	R3.38	3.28	+0.10
	L2.91	3.25	-0.36
subject 4			
	R3.03	3.75	-0.72
	L2.92	4.12	-1.20
subject 5			
	R1.53	2.00	-0.47
	L1.59	2.50	-0.91
subject 6			
	R2.05	1.87	+0.18
	L1.75	4.25	-2.50
subject 7			
	R2.29	3.00	-0.71
	L1.54	2.00	-0.46
subject 8			
	R3.57	4.00	-0.43
	L5.66	6.87	-1.21
subject 9			
	R1.40	2.25	-0.85
	L1.34	1.00	+0.34
subject 10			
	R2.28	3.25	-0.97
	L2.15	3.25	-1.10

mean difference
= -.534

table 1.3

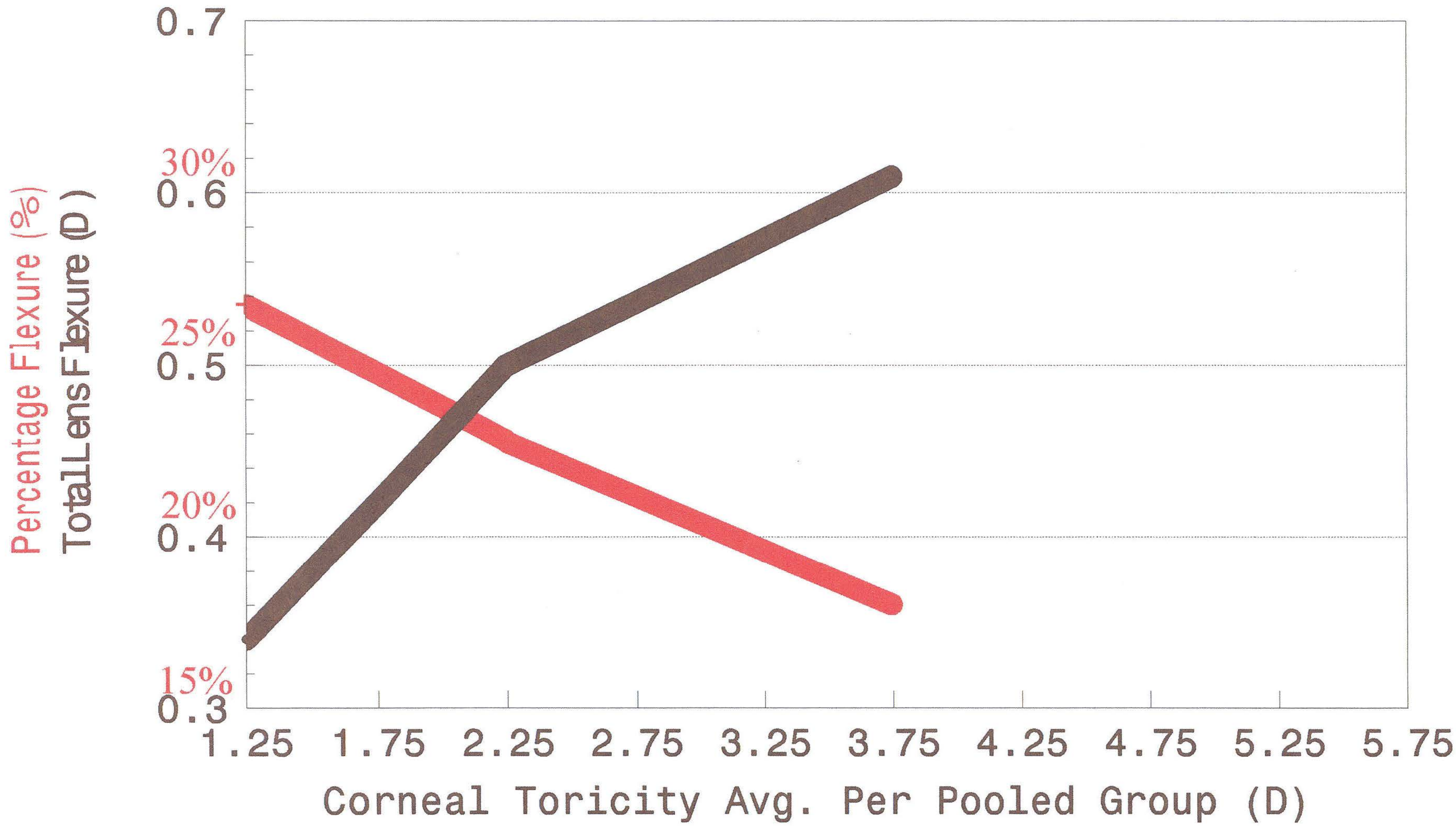
	Eyesys K- Readings	*delta K's*	*Spectacle refraction*
subject one			
	R43.21@180*45.00@090	1.79@090	-6.00=-2.25X180
	L43.26@171*45.42@081	2.16@081	-4.75=-3.25X178
subject two			
	R41.51@009*44.23@099	2.72@099	+2.50=-3.75X015
subject three			
	R43.44@009*46.42@099	3.38@099	-3.00=-3.50X012
	L44.32@161*46.33@071	2.91@071	-4.25=-3.25X175
subject four			
	R42.66@168*45.73@078	3.03@078	-0.50=-3.25X170
	L42.50@003*45.42@093	2.92@093	-0.50=-3.25X010
subject five			
	R44.76@172*46.29@082	1.53@082	-0.75=-1.75X177
	L44.76@163*46.35@073	1.59@073	-1.75=-1.75X175
subject six			
	R42.29@020*44.34@110	2.05@110	+0.25=-3.25X031
	L42.08@163*43.83@073	1.75@073	-0.50=-2.50X165
subject seven			
	R44.00@176*46.29@096	2.29@086	-0.25=-3.00X010
	L43.88@173*45.42@083	1.54@083	-0.50=-2.25X171
subject eight			
	R41.97@165*45.54@075	3.57@075	+2.25=-2.50X167
	L41.41@003*47.07@093	5.66@093	+4.00=-6.00X003
subject nine			
	R43.60@014*45.00@104	1.40@104	-7.00=-1.50X030
	L43.54@154*44.88@064	1.34@064	-7.50=-1.75X160
subject ten			
	R43.26@017*45.54@107	2.28@107	+1.00=-4.00X034
	L43.15@152*45.30@062	2.15@062	+1.00=-3.25X150

Corneal Toricity of Individual Subject Eyes



Graph 1.1

Comparison of Total Lens Flexure vs. Percentage Flexure



Graph 1.2