A Comparison of the Optics of Back Surface Toric (Spherical Front) versus Bitoric Rigid Contact Lenses

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1. INTRODUCTION

Three critical concerns in fitting contact lenses have been defined - physical, physiological, and optical. The physical concern is for the best lens-cornea bearing relationship, which permits optimal lens positioning while maintaining lens mobility. The physiological concern is for adequate oxygen availability, and the optical concern is for just that - optimal optics.[1] Most authors seem to feel that the costly and more complicated design of a bitoric lens, compared to a back toric (spherical front) lens, is necessary for the astigmat. According to some,[2] a bitoric should be the lens of first choice for a toric cornea. Because the tear film is of equal and opposite curvature from the toric base curve of the contact lens, but has a lower index of refraction, the toric base curve is only partially neutralized. This phenomenon is induced astigmatism. Therefore, except for the case when the refractive astigmatism is greater than the corneal astigmatism, a bitoric lens is necessary.[3] The back toric design aligns well with the cornea, but does not provide good acuity in most cases because the induced cylinder compounds physiological astigmatism.[4] The main optical advantage of a bitoric lens is correction of all forms of astigmatism - corneal, physiological, and induced.[2]

The purpose of this study was to compare the optics of two different lens designs for toric corneas, while monitoring the physical and physiological concerns discussed above. The hypothesis was that the optics of a custom designed bitoric lens would be subjectively better than that of a laboratory designed back toric (spherical front) lens. Subjects were provided with one pair of each lens design and, after one

week of wear with each pair, they completed a questionnaire concerning optics and comfort. Clinical assessment included visual acuity, over-refraction, biomicroscopy, fluorescein pattern evaluation, and keratometry.

2. METHODS

Ten patients (seventeen eyes) were seen by me at the Ferris State University College of Optometry. The sample consisted of six males and four females. The mean age was 29.60 years (SD 9.70 years), ranging from 20 to 46 years. The mean corneal toricity was 3.53D (SD 1.43D, range 2.00 to 7.00D), the mean refractive sphere was +1.35D (SD 3.01D, range -3.00 to +7.25D), and the mean refractive cylinder was -3.79D (SD 1.97D, range 1.25 to 8.00D). Subjects selected had at least 2.00D of corneal astigmatism, visual acuity correctable to 20/20, and were present or previous rigid contact lens wearers. The 2.00D corneal toricity value was the minimum amount felt necessary to warrant a toric back surface lens.[5]

Both lens designs were manufactured of the SGP II (Telefocon B) material and the diameter was held constant between the two pair for each subject. I designed bitoric lenses for each patient using keratometry readings, spectacle refraction, and sphero-cylindrical refraction over a nine lens 3.00D Spherical Power Effect (SPE) fitting set. SPE bitoric diagnostic lenses help to assess lens-cornea relationship, centration, movement, and over-refraction.[4] For those subjects who were already wearing a bitoric design successfully, their lenses were used as diagnostic lenses. The base curve was fit on K in the flat meredian and

slightly flat (0.50 to 1.00D, depending on the amount of toricity) in the steeper meredian. The peripheral curves were toric, designed to produce a circular optical zone, which provides a more stable lens.[4] A nearby contact lens laboratory designed the back toric lenses, given the subject's keratometry readings and spectacle refraction. Their formula (spectacle cylinder 1.47) determined the amount of base curve toricity and they also fit on the flat K. (The value 1.47 is the refrective index of plastic.) For the three subjects who needed a toric lens in only one eye, a spherical lens was designed for the fellow eye to be worn with both study lenses. All lenses were verified and all laboratory designed lenses had a spherical front surface on the radiuscope. Pertinent eye dimensions and lens parameters for each subject are shown in Table 1.

Half of the subjects received the bitoric lenses the first week and half received the back toric lenses. They were unaware of which lens design they were wearing during the study. Visual acuity through the lenses, sphero-cylindrical over-refraction, and fluorescein pattern evaluation were done at the time of dispensing. Approximately one week later, these tests were repeated and biomicroscopy and keratometry readings were recorded. At this appointment, patient response was evaluated using the questionnaire in Table 2. The second pair of lenses was then dispensed and the procedure repeated. The questionnaire administered at the end of the second week also asked the patient, "Please give any comments about the wearing, comfort or vision with the lenses, particularly any differences you noticed between the two pair of lenses."

3. RESULTS

All subjects completed the study, and their subjective evaluation of the optics and comfort of each pair of lenses, along with visual acuity and over-refraction, are displayed in Table 3. Vision was rated as good to excellent for all lenses dispensed and only two patients rated the vision differently between the two pair - Patient 1 rated the bitoric lens slightly higher, while Patient 8 rated the back toric lenses slightly higher. At the same time, however, Patient 8 reported spectacle blur upon removal of the back toric lenses. And, although both lenses were rated the same on the questionnaires, Patient 4 commented that the bitoric lenses provided slightly better vision when asked to compare the two pair.

Comfort was rated as good to excellent in all but one case. Patient 9 rated the bitoric lens "somewhat uncomfortable," yet three subjects rated the bitoric lenses most comfortable. It is also interesting that three other subjects commented on comfort, even though they rated the two pair the same - Patients 1, 8, and 10 all found the bitoric lenses more comfortable.

Visual acuity was 20/20 or better through all but three (one bitoric and two back toric) of the 17 lenses, while the cylindrical component of the over-refraction was 0.75D or less with all but three (two bitoric and one back toric) of the lenses dispensed. Upon evaluation of the fit of the lenses, I recorded bubbles under the edge of the O.D. back toric lens on Patient 4, and bubbles and more significant dimple veiling O.U. for the back toric lenses on Patient 5. Figure 1 compares corneal curvatures to contact lens base curves (flat and steep meredians for each lens design)

and indicates a tendency for the back toric design to fit flatter on the steep meredian of the cornea.

4. DISCUSSION

In several cases, the two lens disigns were very similar. Five of the 17 eyes (29%) wore bitoric and back toric lens designs that were within 0.25D in both principal meredians. A comparison of spectacle cylinder versus corneal cylinder in Figure 2 shows a slight tendency for corneal cylinder to be less than spectacle cylinder as the amount of astigmatism increases. But there appears to be no direct relationship between those patients with higher amounts of astigmatism and the cases where the two lens designs were similar.

According to the data, either lens design provides adequate optics, both subjectively and objectively, which does not support my hypothesis. However, it is interesting that, of the seven patients who noticed a difference in comfort, six found the bitoric design most comfortable. I feel that the difference in comfort is due to the flatter fit of the back toric design. This could be creating more lid sensation and resultant decreased comfort with that design. The flat fit also seems to be responsible for the bubbles under the lens edge and dimple veiling noted in two subjects.

Concerning Patient 10, the relatively high amount of cylindrical over-refraction with both lens designs was due to all lenses riding low, despite a minus carrier lenticular edge. The patient was not viewing through the optical center of the lenses. This has been a chronic problem for Patient 10, as he arrived for the initial fitting wearing spherical lenses that

rested in a deep groove in the lower cornea and conjunctiva. Of the two lens designs tested here, the bitoric lens stayed up and out of the groove most of the time, while the back toric lens rode in the groove the majority of the time. The better corneal match with the bitoric lens design seemed to provide a better fit for this patient.

I will also comment on the inconsistent data for Patient 5. With a relatively insignificant over-refraction in the right eye with the bitoric design, one would expect the acuity to be better than 20/25. Patient 5 had a severe cold the week the bitoric lenses were tested, and I think mucous in the tear film was responsible for the decreased acuity. (Especially since the subject read 20/20 through the same lens the week before at dispensing.)

I propose that there are certain cases where a back toric design is very adequate, although there are other cases where a bitoric design is necessary. I suggest that the practitioner determine the base curve necessary for a good corneal fit using keratometry readings and SPE fitting lenses, as described in the methods section. Then determine the amount of base curve toricity necessary for a back toric design using the formula (spectacle cylinder / 1.47). If the two calculations result in the same back surface toricity, order the lens as a back toric (spherical front) design. It will cost less and probably be the same lens you will get if you pay for a "bitoric." On the other hand, do not sacrifice a good corneal fit and patient comfort for cost. If the base curve is flatter with the back toric calculation, then a bitoric design is necessary to provide optimal physical fit and physiological response.

ACKNOWLEDGEMENT

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TABLE 1: Eye Dimensions and Lens Parameters

Patient	K-readings	Spectacle Rx	Bitoric BC	Bitoric Power	Back Toric BC	Back Toric Power	OAD	Bitoric FOR	Back Toric FOR
1 OS	44.00@005,47.00@095	-1.50-3.00X004	7.62/7.27	-1.25/-3.50	7.66/7.31	-1.75/-4.00	9.5	7.80/7.73	7.86
2 OD	42.00@176,46.00@086	+0.50-4.50X175	8.02/7.51	+0.50/-2.87	8.04/7.51	+0.50/-3.50	9.5	8.01/7.90	7.92
OS	41.75@014,46.00@104	+0.75-4.50X014	7.99/7.44	+0.62/-2.75	8.07/7.58	+0.37/-3.50		7.92/7.86	7.96
3 OD	42.50@012,46.00@102	+3.00-3.75X014	7.78/7.39	+2.75/pl.	7.97/7.50	+3.00/-0.25	9.5	7.53	7.60
OS	42.00@163,46.00@073	+3.50-5.00X165	7.93/7.38	+3.00/-1.00	8.01/7.44	+3.25/-1.25		7.57	7.63
4 OD	40.50@005,44.25@095	+7.25-3.50X180	8.30/7.70	+7.75/+4.00	8.33/7.85	+8.00/+5.00	9.7	7.37/7.34	7.44
OS	41.00@009,44.00@099	+7.00-2.75X012	8.06/7.79	+6.75/+4.50	8.18/7.87	+7.75/+5.25		7.34/7.32	7.32
5 OD	41.12@008,43.62@098	-1.75-2.50X012	8.23/7.76	-1.75/-3.25	8.20/7.86	-2.00/-4.00	9.5	8.42/8.20	8.46
OS	41.00@170,43.87@080	-1.50-2.25X172	8.21/7.89	-1.75/-3.00	8.19/7.94	-1.87/-3.50		8.49/8.30	8.44
6 OD	42.00@010,44.00@100	+1.25-2.00X025	8.08/7.78	+1.25/pl.	7.99/7.69	+1.00/-1.25	9.0	7.90/7.74	7.90
OS	43.75@002,45.75@092	-2.00-1.25X167	7.69/7.48	-2.00/-3.00	7.70/7.48	-1.75/-3.50		7.91/7.77	7.92
7 OD	42.00@176,45.00@086	+0.50-3.50X177	7.98/7.58	+0.50/-2.75	7.98/7.58	pl./-2.25	9.5	7.99	7.98
OS	42.12@001,45.25@091	+0.25-3.50X008	7.94/7.48	+0.12/-3.00	7.92/7.57	-0.25/-2.75		7.95	8.00
8 OD	42.25@004,49.00@094	+3.75-8.50X002	7.98/7.06	+3.50/-3.25	7.99/7.04	+3.75/-3.50	8.7	7.53	7.54
OS	42.00@176,49.00@086	+3.75-8.25X174	8.02/7.08	+4.00/-3.75	7.96/7.08	+3.75/-3.50		7.60	7.55
9 OS	43.25@002,45.50@092	-3.00-2.75X002	7.68/7.32	-3.75/-5.25	7.69/7.44	-3.50/-5.25	9.2	8.14/7.98	7.90
10 OD	43.50@001,46.50@091	+1.25-3.00X014	7.68/7.32	+1.25/-1.25	7.75/7.44	+1.12/-1.25	9.5	7.58/7.49	7.59

TABLE 2: Patient Questionnaire for Evaluation of Rigid Gas Permeable Lens Designs.

1. How would you rate your vision through these lenses on the following scale?

    a) excellent
    b) good
    c) fair
    d) poor

2. How would you rate the comfort of these lenses on the following scale?

    a) very comfortable
    b) comfortable
    c) somewhat uncomfortable
    d) very uncomfortable

3. How would you rate your overall satisfaction with these lenses on the following scale?

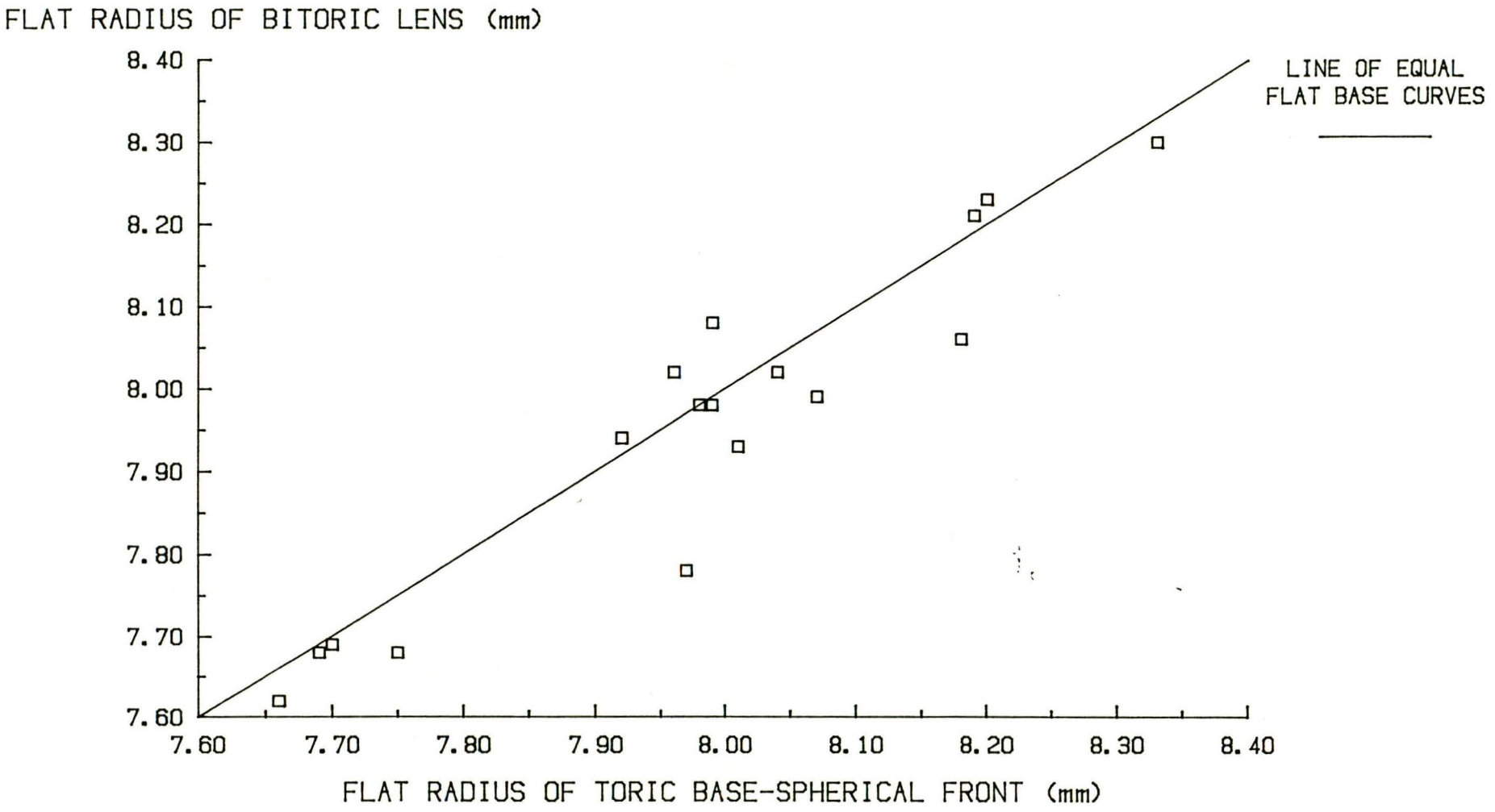
    a) very satisfied
    b) satisfied
    c) not satisfied
    d) dissatisfied and wear discontinued

TABLE 3: Evaluation of Optics and Comfort

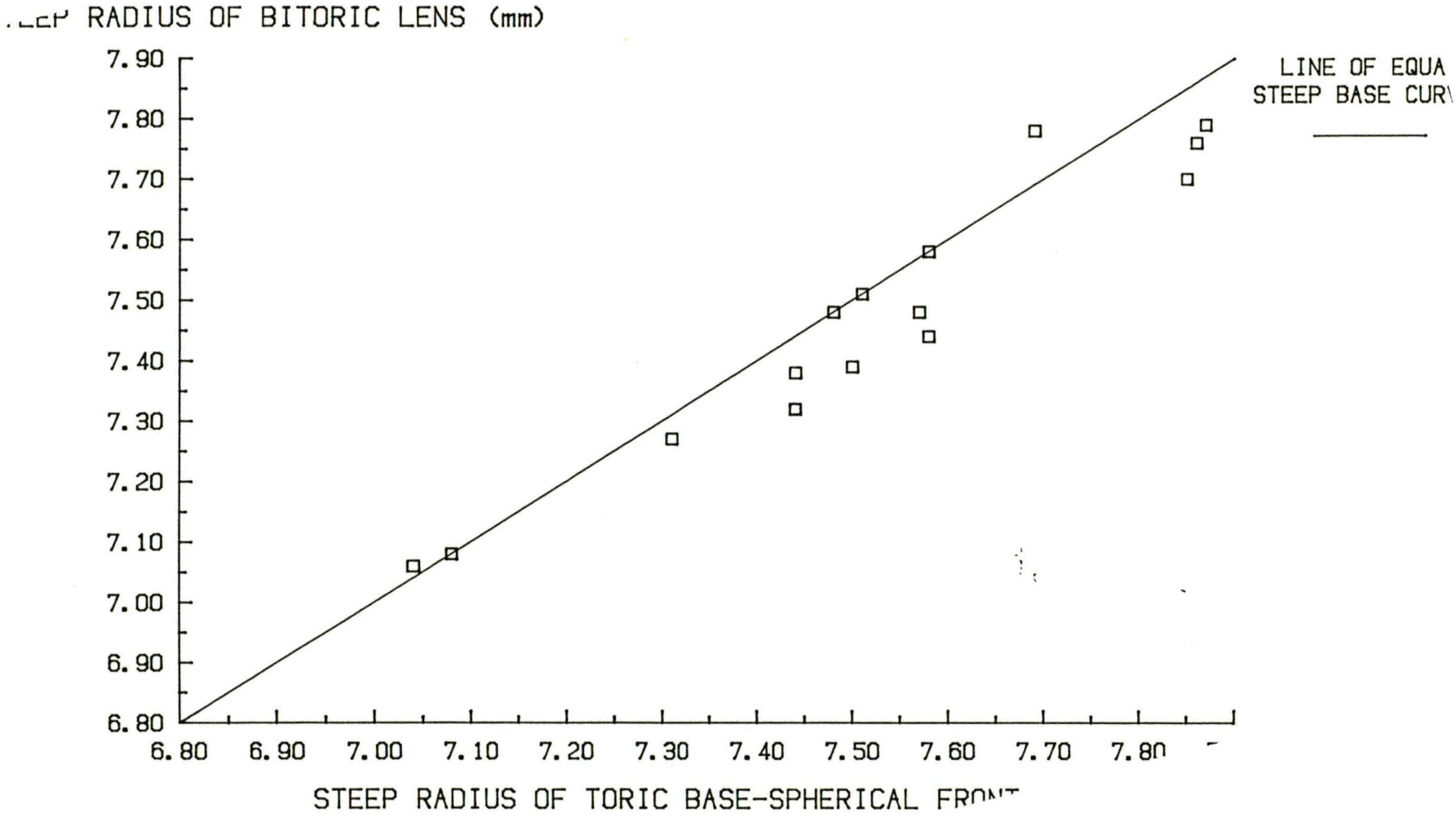
Patient		Bitoric VA	Bitoric OR	Bitoric "Vision"	Bitoric "Comfort"	Back Toric VA	Back Toric OR	Back Toric "Vision"	Back Toric "Comfort"
1	OS	20/15	pl. sph.	excellent	comfortable	20/15	pl. sph.	good	comfortable
2	OD	20/15	pl.-0.25X068	good	very comfortable	20/15	-0.25-0.50X075	good	very comfortable
	OS	20/15	-0.25-0.25X127			20/15	-0.25 sph.		
3	OD	20/20	pl. sph.	excellent	very comfortable	20/20	+0.25 sph.	excellent	comfortable
	OS	20/20	pl. sph.			20/20	+0.50 sph.		
4	OD	20/15	+0.25 sph.	good	very comfortable	20/15	+1.00 sph.	good	somewhat uncomfortable
	OS	20/15	+0.75-0.25X095			20/15-2	+1.00-0.50X104		
5	OD	20/25+2	pl.-0.50X015	good	very comfortable	20/15-3	+0.50 sph.	good	very comfortable
	OS	20/20	+0.25-0.50X160			20/25+1	+1.25-0.75X133		
6	OD	20/20-1	+0.25-0.50X051	good	very comfortable	20/20	pl. sph.	good	very comfortable
	OS	20/15-1	+0.25-1.00X168			20/20+1	pl.-0.50X105		
7	OD	20/15-1	-0.25 sph.	excellent	comfortable	20/15	+0.25 sph.	excellent	somewhat uncomfortable
	OS	20/15	pl.-0.25X079			20/15-3	+0.50-0.75X142		
8	OD	20/15	+0.50-0.25X145	good	comfortable	20/15-1	pl. sph.	excellent	comfortable
	OS	20/15	+0.50 sph.			20/15	+0.50 sph.		
9	OS	20/15	+0.25 sph.	excellent	somewhat uncomfortable	20/15	pl.-0.50X127	excellent	comfortable
10	OD	20/20-3	+0.25-1.75X025	good	comfortable	20/25-3	+1.25-1.25X165	good	comfortable

* All patients rated their overall satisfaction with both lens designs the same.

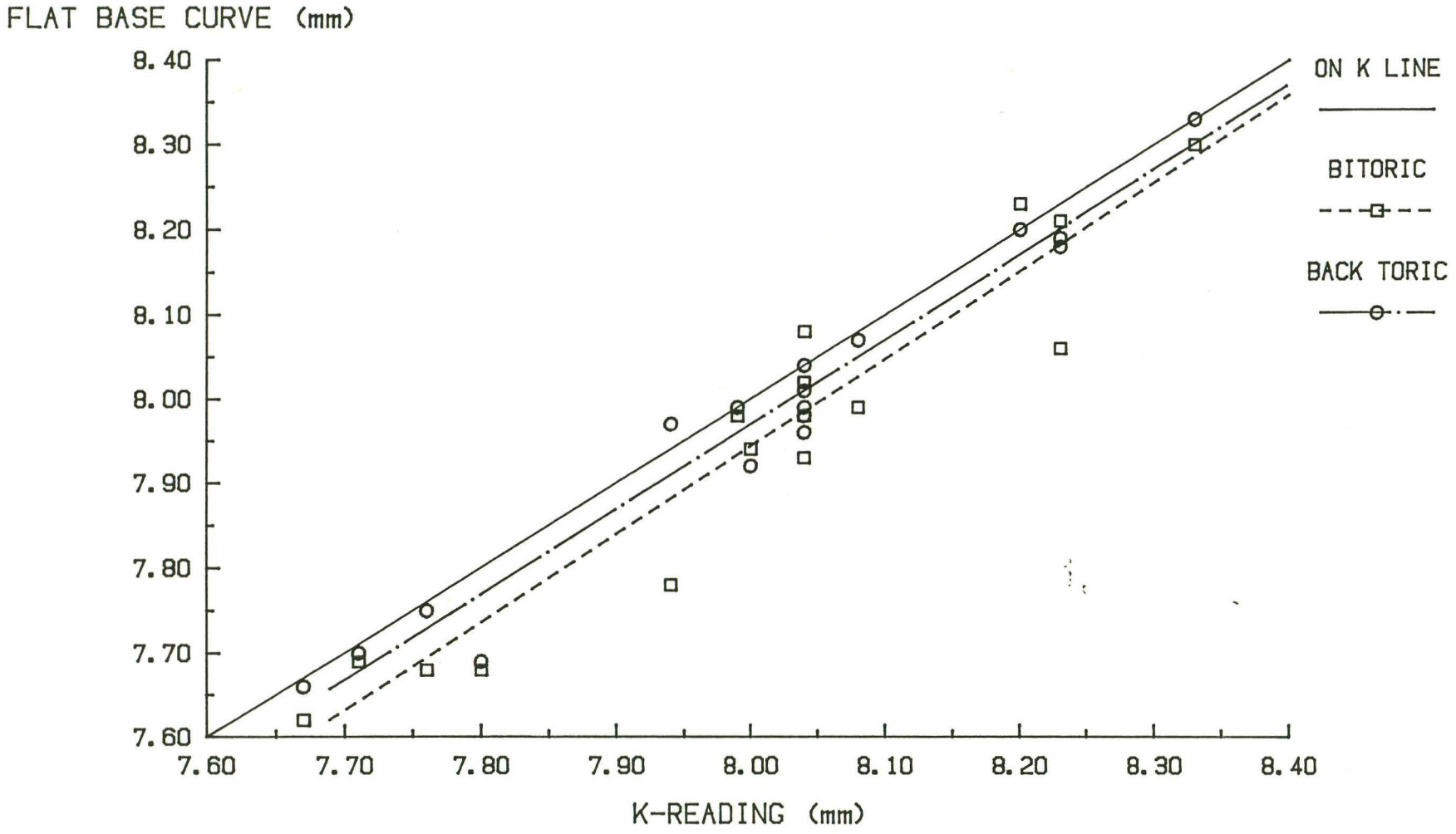
FLAT MERIDIAN BACK SURFACE RADIUS
TORIC BASE–SPHERICAL FRONT VS BITORIC



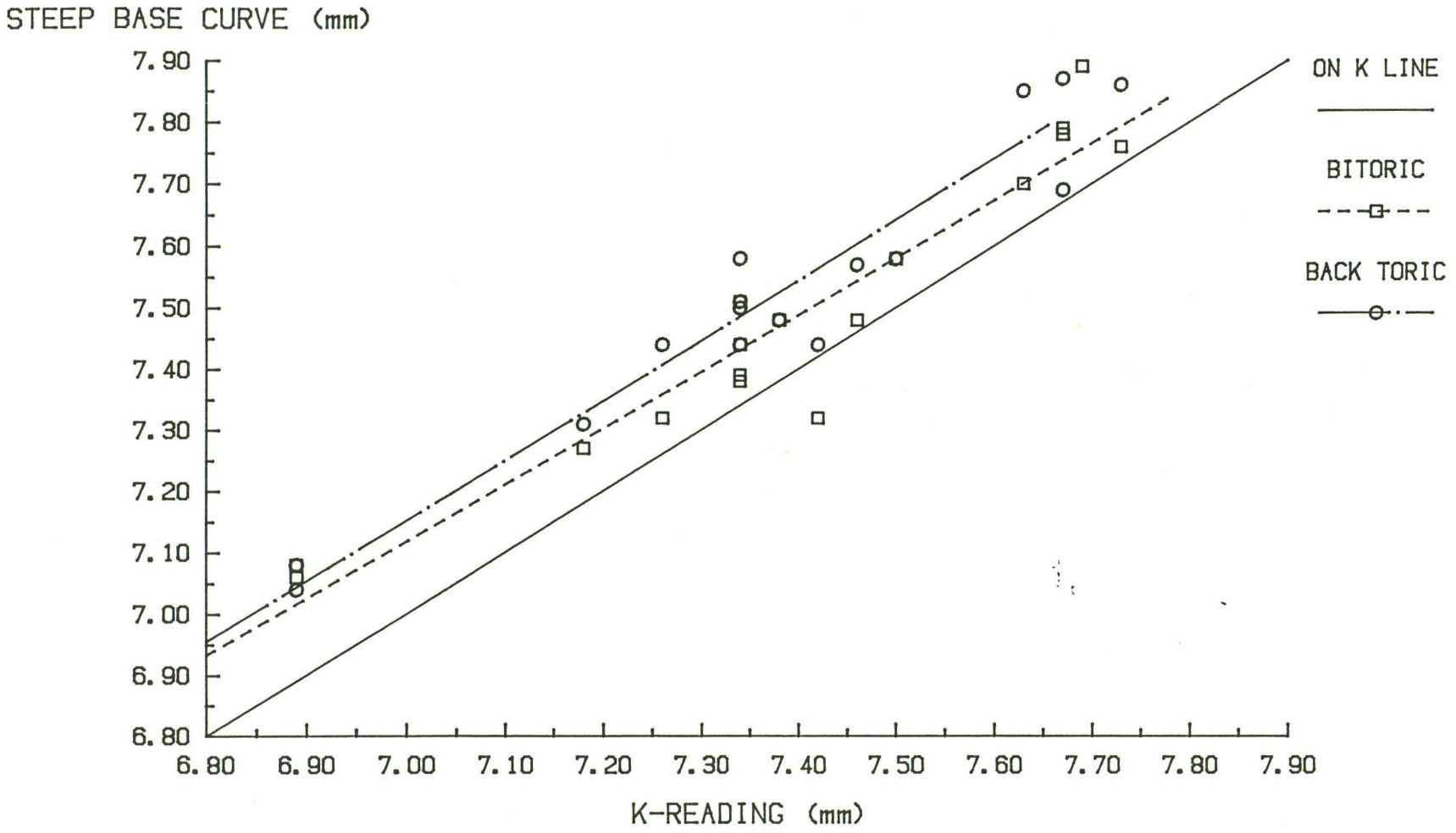
BACK SURFACE RADIUS
BASE–SPHERICAL FRONT VS BITORIC



FLAT K–READING VERSUS LENS FLAT MERIDIAN
TORIC BASE–SPH FRONT VS. BITORIC



STEEP K–READING VERSUS LENS STEEP MERIDIAN
TORIC BASE–SPH FRONT VERSUS BITORIC LENSES



SPECTACLE CYLINDER VS CORNEAL TORICITY