THE EFFECT OF DIFFERENT MONOVISION CONTACT LENS POWERS ON THE VISUAL FUNCTION OF EMMETROPIC PRESBYOPIC PATIENTS (AN AMERICAN OPHTHALMOLOGICAL SOCIETY THESIS)

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ABSTRACT

Purpose: To evaluate the effects of three increasing powers of monovision contact lenses on both objective and subjective vision in emmetropic presbyopic patients.

Methods: A prospective single-center study was conducted on 50 emmetropic presbyopic patients with a mean age of 55.4 ± 4.3 years (range, 50 to 66). Each patient wore for 1 week a +0.75 D, +1.50 D, and +2.50 D contact lens in the nondominant eye. Objective testing after each week included near and distance visual acuity, distance stereopsis, distance contrast sensitivity, and measurement with two different aberrometers of spherical equivalent, defocus, spherical aberration, and total higher-order aberrations. Subjective testing included questionnaire responses regarding vision under various conditions after 1 week with each lens power. Statistical tests were performed to determine significant differences from pretreatment.

Results: Binocularly, mean uncorrected near visual acuity increased in both eyes ($P < .01$) with each increase in contact lens power. Monocular distance vision decreased significantly with each increasing lens power, but binocular distance vision remained unchanged from pretreatment. Distance stereopsis decreased significantly with increasing contact lens powers ($P < .01$ with the +2.50 D lens power). Photopic and mesopic distance contrast sensitivity decreased significantly with progressive increase in power. Wavefront analysis showed a change in defocus in the myopic direction, but no increase in higher-order aberrations.

Conclusions: In emmetropic presbyopes, near vision improved with increased lens power, but distance vision was degraded objectively and subjectively. The +1.50 D power provided optimal near and distance vision for monovision contact lens wear, as measured by a patient questionnaire and a series of eight tests for evaluating various aspects of visual function. The objective and subjective tests used in this study will provide a baseline for evaluation of surgical procedures performed for near vision enhancement.

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INTRODUCTION

Presbyopia is a condition of insufficient accommodative amplitude for clear near vision. The near point of the eye recedes toward the far point so that small objects must be held farther from the eye to be clearly visualized. Insufficient accommodative amplitude increases with advancing years. At age 8, average amplitude of accommodation of 14.0 to 16.0 diopters (D) declines to10.0 ± 2.0 D by age 25, 6.0 ± 2.0 D by age 40, and 1.5 D ± 1.0 D by age 60 (Figure 1).[1-3] A person unable to maintain 3.0 D of accommodation for any length of time is considered to have symptoms of presbyopia.[4]

No study on the age-related prevalence of accommodative failure is available.[5] However, because development of presbyopia is universal and linked with age, prevalence can be inferred from demographic studies. In the United States, for example, 76.5 million persons were born during the 19 years following World War II (1946 to 1964) and are known as the baby-boomer generation.[6] In 2005, these baby boomers were between the ages of 41 and 59, an age range that would include many existing or soon-to-be presbyopes.

Some of these 76.5 million baby boomers were myopic in their youth and likely wore spectacles or contact lenses for vision correction, or had photorefractive keratectomy (PRK) or laser in situ keratomileusis (LASIK) after it became available. The emmetropes (spherical equivalent = +0.75 D to –0.75 D), on the other hand, had no need for an optical correction for near or distance vision in their younger years. This group numbers 41 million persons in the United States (Figure 2)[7,8] and, unlike the myopes who may have delayed onset of presbyopic symptoms, emmetropes experience symptoms of presbyopia in their mid 40s and are frequently frustrated with their inability to see well at near without an optical aid. A recent study showed presbyopes to have worse vision-related quality of life compared with younger emmetropic persons.[9]

Many persons in this large group of emmetropic presbyopes are now interested in a monovision contact lens correction or one of the surgical alternatives that could provide them with some freedom from spectacles for near vision tasks. Monovision contact lenses have been used for years, and because these patients do not require correction for distance, they can potentially be fitted with only one contact lens for near correction. The ophthalmology community has also responded with surgeries that include monovision PRK,[10,11] pseudoaccommodative advanced surface ablation,[12] multizone LASIK,[13] monovision LASIK,[14-20] scleral expansion surgery,[21] phakic intraocular lens implantation,[22] intraocular lenses,[23,24] and conductive keratoplasty (CK).[25] Indeed, surgical correction of presbyopia is considered the new frontier in refractive surgery.[26-28]

Evaluation of surgical modalities for presbyopia requires a point of reference for comparing success of the procedures and the postoperative quality of vision, measured both objectively and subjectively. A rigorous evaluation method would entail a comparison with nonsurgical treatments, such as monovision contact lenses. There appears to be no published data on the results of different powers of monovision contact lenses on both objective and subjective vision, and this study may serve as the first such investigation.

Briefly, the methods used in this study included pretreatment and posttreatment evaluation of emmetropic presbyopic patients who

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wore increasing powers of monovision contact lenses (+0.75 D, +1.50 D, +2.50 D), 1 week for each lens power. The evaluation methods included traditional assessments of visual function (refraction, near and distance visual acuity, stereopsis, contrast sensitivity), and extensive subjective assessments; in addition, wavefront analysis was performed with two different aberrometers before treatment and with each power of contact lens in place.

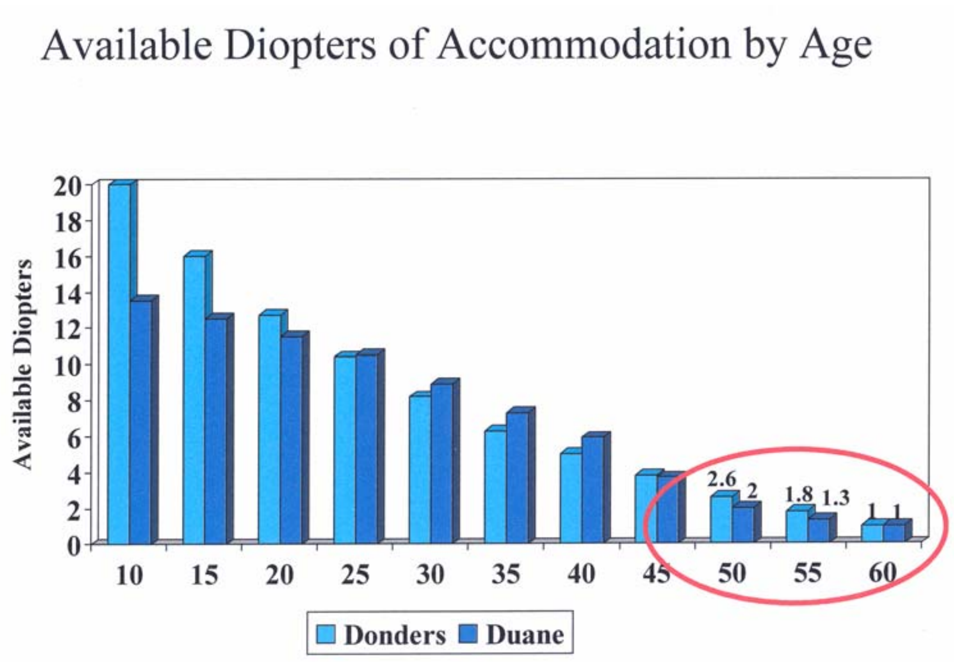

FIGURE 1

Available diopters of accommodation with age. Diminishing accommodation with age is evident. At age 50, accommodation is less than 3 diopters. Data from Duane[2] and Donders.[1]

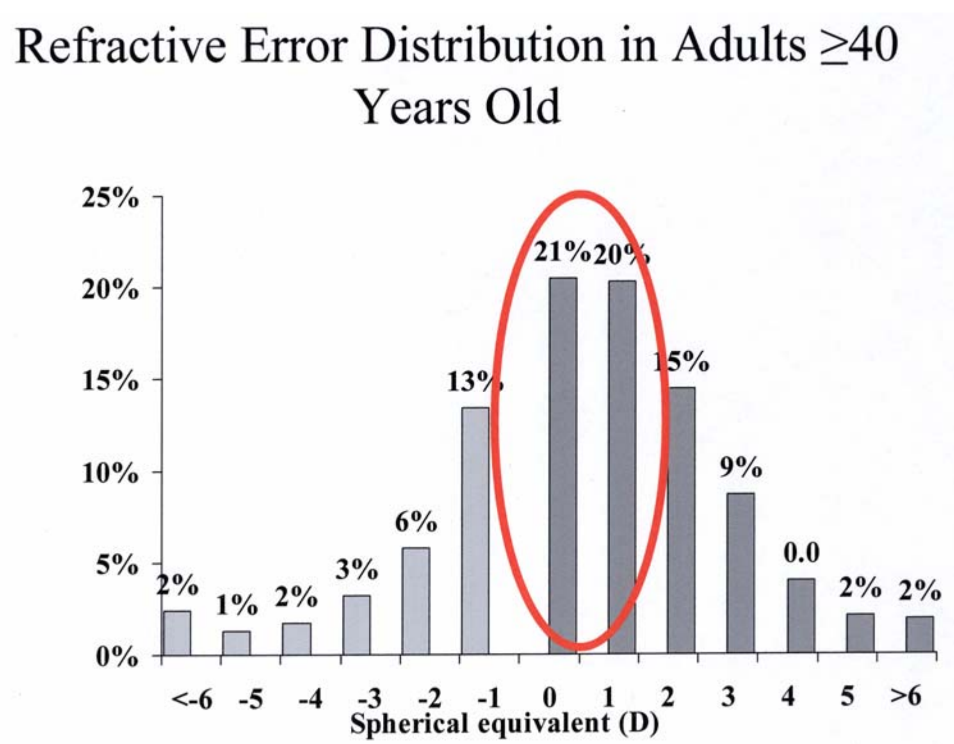

FIGURE 2

Refractive error distribution in adults 40 years of age or older. Emmetropic and +1.0 D persons constitute 41% of the population of 40 or older persons. Data from Tielsch et al.[7]

The reasons for studying emmetropic presbyopes were that (1) this population group is large, 41 million persons in the United States, many of whom desire to be mostly free of spectacles; (2) this population would be expected to retain good distance vision in one eye after a monocular correction for near in the other eye; and (3) this group enjoyed good distance and near vision until the onset of presbyopia. Therefore, they may be more sensitive to the differences they perceive with a monovision correction in the subjective assessment part of the study. All 50 of the patients reported here had presented at the author's clinic seeking decreased dependence on reading glasses.

Findings on three powers of monovision contact lenses tested in the same emmetropic presbyopic patients are presented here with the hope of providing information for the contact lens practitioner on how such patients react to increasing powers of contact lenses, whether any of the powers tested had a detrimental effect on vision, and whether there was an optimal power for near vision in a monovision system. This would guide the practitioner on choice of lens power (finding the correction "sweet spot") and avoid the need to acquire such information through experience. Furthermore, and of equal importance, is the application of the findings to the evaluation of surgical procedures for presbyopia. Postsurgical subjective results, such as stereopsis and contrast sensitivity, and subjective results, such as visual complaints (eg, glare, halos), and patient satisfaction can be compared with the results obtained in this study with contact lenses. In fact, postsurgical results could be plotted on the same line-plot figures or bar graphs that are presented for the contact lens powers for a direct comparison of contact lens results with postsurgical results.

The application of these results to the evaluation of monovision excimer laser procedures, scleral expansion surgery, intraocular lens implantation, and CK, performed on previously unoperated presbyopic eyes to improve near vision, has been mentioned previously. In addition, these results could be applied to evaluation of procedures for two other groups of persons who now have insufficient accommodation for near vision: (1) the post-LASIK presbyopes who have had their distance vision corrected, and (2) the emmetropic persons who have had cataract surgery and have been implanted with a conventional intraocular lens set for a distance focal point. Many of these patients are seeking alternatives to reading glasses. It is hoped that the data provided by this study will provide a benchmark for evaluation of monovision contact lens and monovision surgical procedures and will benefit a great number of patients who have deficient near vision because of presbyopia.

METHODS

PATIENT SELECTION

Presbyopic patients presenting for evaluation for improvement in their near vision without the use of reading glasses were asked about interest in study participation and were screened for eligibility. Eligibility criteria included binocular uncorrected distance visual acuity (UCDVA) no worse than 20/30, a manifest refractive spherical equivalent (MRSE) ranging from +0.75 D to –0.75 D, and less than or equal to 1.00 D of cylinder. MRSE had to be stable within 1.00 D over the 6 months preceding enrollment. Patients also had to be healthy and have no significant medical history and not be taking any systemic medications. Patients with residual, recurrent, or active ocular diseases, corneal abnormalities, or previous ocular surgery were excluded from study participation. Patients were given informed consent for the institutional review board–approved clinical study before any testing was performed. Fifty patients were found to be eligible.

Prior to any clinical testing, patients completed questionnaires on their psychosocial and visual characteristics (Appendix A). The pretreatment questionnaire had five pages and included questions about current vision, use of corrective lenses, and the patient's reasons for wanting to decrease dependability on reading glasses. Also included were questions on (1) current and typical use of corrective lenses for distance vision, (2) current and typical use of corrective lenses for near vision, and (3) ability to see the following without reading glasses: newspaper headlines, automobile dashboard, computer screen, wrist watch, cellular phone, and a medicine bottle label. This was followed by questions on the patient's experiences with his or her vision, including (1) clarity of vision, (2) problems with halos, rings, or starbursts around objects or lights, (3) glare or light sensitivity, (4) problems with haze or foggy vision, and (5) ability to judge distances. Patients were to respond on a scale of 1 to 10, where 0 stood for "no problem" and 10 stood for "disabling problem."

TESTING PROCEDURES

To fully assess the monovision effect on each patient, eight clinical tests appropriate for evaluating various aspects of visual function were performed at each visit, in addition to the patient questionnaire. These tests for all eyes included refraction by phorometer, determination of eye dominance, distance and near visual acuity, stereopsis, photopic and mesopic contrast sensitivity, and wavefront error measurements. These tests and their sequence are described in detail below.

Determination of Sighting Dominance

The goal of sighting dominance determination was not only to determine which of the patient's eyes was dominant, but also to demonstrate the dominant eye to the patient. Demonstration of the dominant eye was important because this plano presbyopic group of patients had excellent UCDVA and would be using their dominant eye for distance viewing after monovision lens fitting. Most tests for eye dominance, with the exception of some self-administered tests used by sportsmen, do not demonstrate eye dominance to the patient.

For the test used, the Interactive Eye Dominance Test, patients were instructed to sit with shoulders and feet square to the 20/400 Snellen E letter in the examination room. They were handed an 8¾ × 4¾-inch card containing a center hole with a diameter of 1¼ inch. With both eyes open and observing the 20/400 Snellen E letter, the patient was to hold the card at arm's length and to center the card just below the target. The patient then raised the card so that the distance target was perfectly centered in the middle of the hole in the card while both eyes were open. The patient then moved the card toward his or her face, all the while keeping the "E" in the center of the hole. The patient repeated these steps several times. The dominant eye was determined to be the eye the patient repeatedly used at distance with the card. Patients were then asked to observe which eye they were using to view the "E" to show them which eye was dominant. Figures 3 through 6 show the procedure.

Monovision Contact Lens Trial

Prior to placing a contact lens on any eye, a "loose-lens" test was administered, where the tester held up a +0.75 D, +1.50 D, and +2.50 D lens in front of the nondominant eye to demonstrate whether distance vision would be tolerable. If a patient could not find a satisfactory endpoint, the monovision trial was not performed. All 50 screened patients passed the loose-lens test.

After completing initial clinical testing, patients began the trial of wearing contact lenses of increasing add powers (+0.75 D, +1.50 D, and +2.50 D), 1 week for each of the three powers. For the first week, they were fitted with a +0.75 D contact lens on their nondominant eye and were instructed to wear that lens for 1 week. The lens type was either a Soflens 66 extended-wear contact lens (base curve: flat/medium, diameter: 14.2 mm) (Bausch & Lomb, Rochester, New York) or a Focus Night and Day contact lens (base curve: 8.6, diameter: 13.8 mm) (Ciba Vision, Duluth, Georgia), depending on which lens gave the best corneal coverage, centration, and comfort. A 1-week contact lens adaptation period was deemed sufficient for this study. This period was shorter than the usual contact lens adaptation time. Short-term neural adaptation happens in hours to days, but long-term neural adaptation can take weeks to months. Longer-term contact lens wear was not practical in this study because three increasing power lenses were being used. The 1-week period was chosen as long enough to evaluate short- term adaptation but still practical for the subjects in the study.

Questionnaires

Following 1 week of wearing the first test lens power, +0.75 D, patients were given a questionnaire (Appendix B) to evaluate their function during the preceding week. This questionnaire, "Assessment of functional vision with use of monovision contact lenses," included essentially the same questions on lens and spectacle wear and functional vision as the pretreatment questionnaire with the additional question on rating the convenience or inconvenience of wearing the contact lens (scale of 0 to 10). They also underwent clinical testing for uncorrected distance and near VA, distance stereopsis, distance contrast sensitivity, and dilated wavefront measurements with the lens in place. After a careful slit-lamp examination was performed, the next level of monovision, a +1.50 D lens, was placed on the patient's eye. Patients returned a week after that to repeat the same clinical testing, after which a +2.50 D lens was placed on the patient's eye. At the end of the third week, the patient returned to repeat the same clinical testing, and the contact was removed from the patient's eye.

Patients were instructed on all the risks and signs of complications from wearing an extended-wear lens. They were given a telephone number allowing them to reach a study researcher at any time in case problems were encountered. Patients who lost their contact lens during their week-long trial returned at their earliest convenience, had their contact lens replaced, and continued on until 1 week of lens wear had been completed. Following completion of the contact lens power testing, patients were randomized to two different monovision surgical procedures (CK and LASIK). These results will be compared to the visual and subjective results with the different powers of contact lenses in future publications.

To keep the naming convention consistent, the eye that will have the monovision contact lens will be called the treated eye, the dominant eye will be referred to as the untreated eye, and both eyes together will be called OU. At the initial evaluation, each patient's UCDVA in the treated eye, the untreated eye, and OU was taken at 13 feet on an EDTRS visual acuity eye chart. All visual acuities were recorded in a Snellen acuity and then converted to a logMAR acuity, using the formula logMAR = $\log_{10}(X/20)$, with X = Snellen denominator. The average logMAR UCDVA and best-corrected distance visual acuity (BCDVA) of all patients were calculated, and then converted back into a Snellen acuity using the reverse formula: $X = (10^{logMAR}) \times (20)$. During the monovision trial, patients returned with the monovision contact lens power that had been worn that week in the treated eye and had UCDVA measured in the treated eye, the untreated eye (which had no lens correction), and OU. For each monovision power, the average logMAR value of all patients was determined and then converted back into a Snellen acuity using the same formula given above.

Near Visual Acuity

At the patient's initial and weekly examinations, near visual acuity (uncorrected near visual acuity [UCNVA]) was measured in the untreated eye, the treated eye, and OU. Near acuity was measured at 14 inches using the Alza near vision chart (Palo Alto, California). The near acuity card was designed such that the card is 14 inches away from the patient's eye when a bead on a 14-inch string is placed at the patient's lateral canthus.

Distance Stereopsis

Distance stereoacuity of all patients was measured using the Optec 3500 (Stereo Optical, Inc, Chicago, Illinois) device. At the initial visit, patients had distance stereoacuity measured without correction. During the monovision trial, distance stereoacuity was measured at each visit with the monovision contact lens in the treated eye and no correction in place over the untreated eye.

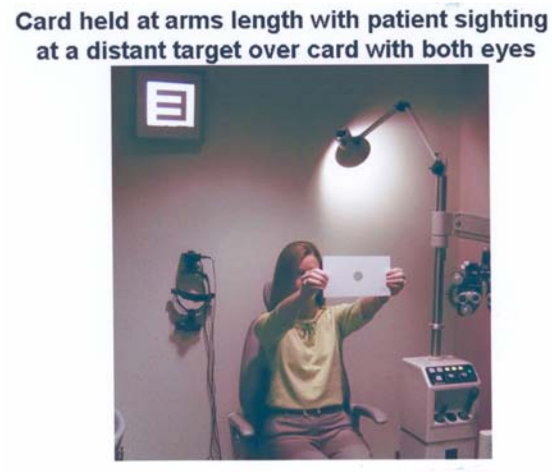

FIGURE 3

Testing for eye dominance. The card is held at arm's length with patient sighting at a distant target over card with both eyes.

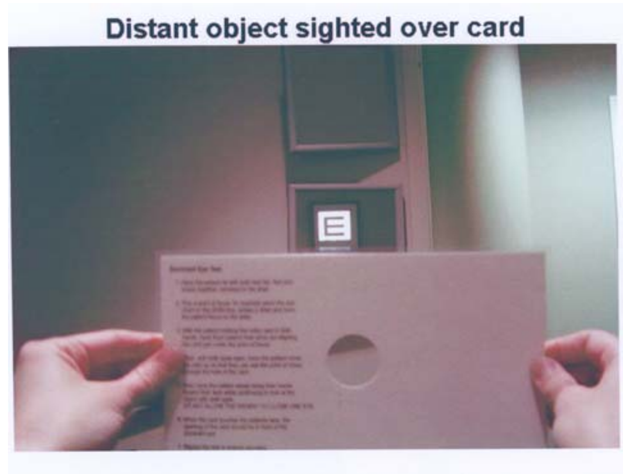

FIGURE 4

Testing for eye dominance. A distant object is sighted over the card.

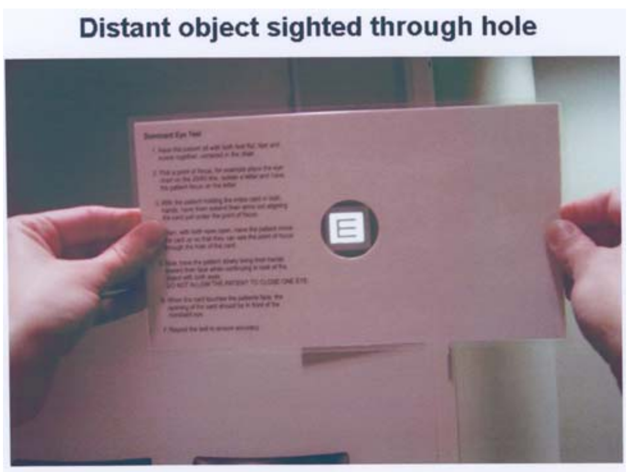

FIGURE 5

Testing for eye dominance. The distant object is sighted through hole in the card.

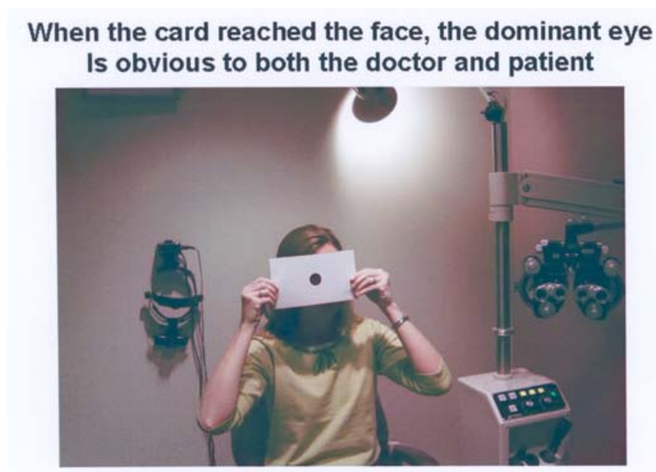

FIGURE 6

Testing for eye dominance. When the card reaches the face, the dominant eye is obvious to both the doctor and patient.

Distance Contrast Sensitivity Testing

At the initial visit, the patient's distance contrast sensitivity was tested with the Optec 3500 (Stereo Optical, Inc, Chicago, Illinois) device without any correction in place. This device was used for all contrast testing in this study. The patient's mesopic and photopic contrast sensitivity was measured for the treated eye, the untreated eye, and OU. Settings for mesopic were 6 cd/m^2 (which corresponds to a digital LED display of 6 ± 1). Photopic luminance was set at 85 cd/m^2 (which corresponds to a LED display value of 35 ± 1). The patient was instructed to view each row of spatial frequencies and report whether the contrast lines were tilting to the left, right, or up, or if he or she was unable to see any lines at all. When two of the patient's responses were incorrect, the contrast value of the last correct response was recorded as the patient's contrast sensitivity for that spatial frequency. Contrast testing was repeated at each return evaluation with the contact lenses in place as described above.

Wavefront Measurements

Upon presenting for the qualifying examination, patients' eyes were dilated for a fundus examination and for a wavefront evaluation. When the pupil had dilated to at least 6.5 mm, a diagnostic wavefront examination was performed on both eyes using the Hartmann-Shack-based Alcon LadarWave aberrometer (Alcon Surgical, Fort Worth, Texas), and the ray-tracing-based Visual Function Analyzer (Tracey Technologies, LLC, Houston, Texas). Readings were recorded at a 6.0-mm diameter for both devices, and an additional value was recorded with the Tracey device at a 3.0-mm pupil. The Zernike values were recorded in ANSI standards format. This procedure was repeated at each subsequent contact lens examination, with the wavefront being performed over the contact lens.

Error in the expected change in SE measurement on both of the aberrometers was calculated as shown:

- (Actual SE Value with +0.75 D lens) – (SE Expected Value) = (SE Error with +0.75 D lens)
- (Actual SE Value with +1.50 D lens) – (SE Expected Value) = (SE Error with +1.50 D lens)
- (Actual SE Value with +2.50 D lens) – (SE Expected Value) = (SE Error with +2.50 D lens)

The error was defined as the actual SE value over a given power contact lens minus the expected SE value. The expected SE value was defined as the measured baseline value minus the contact lens power.

Error in the expected change in the defocus term on each of the aberrometers was calculated as shown:

- (Actual Defocus Value with +0.75 D lens) – (Expected Defocus Value) = (Defocus Error with +0.75 D lens)
- (Actual Defocus Value with +1.50 D lens) – (Expected Defocus Value) = (Defocus Error with +1.50 D lens)
- (Actual Defocus Value with +2.50 D lens) – (Expected Defocus Value) = Defocus Error with +2.50 D lens)

The error was defined as the actual defocus value over a given power contact lens minus the expected defocus value. The expected defocus value was defined as the measured baseline value minus the microns that correspond to that level of contact lens power for each given pupil size.

Error in the spherical aberrations term on each of the aberrometers was calculated as shown:

- (Actual Spherical Aberration Value with +0.75 D lens) – (Spherical Aberration Expected Value) = (Spherical Aberration Error with +0.75 D lens)
- (Actual Spherical Aberration Value with +1.50 D lens) – (Spherical Aberration Expected Value) = (Spherical Aberration Error with +1.50 D lens)
- (Actual Spherical Aberration Value with +2.50 D lens) – (Spherical Aberration Expected Value) = Spherical Aberration Error with +2.50 D lens)

The error was defined as the actual Spherical Aberration value over a given power contact lens minus the expected Spherical Aberration value. The expected Spherical Aberration value was defined as the measured baseline value. Therefore, any significant error would show an increase or decrease in spherical aberration resulting from the contact lenses.

Orbscan Topography

At the initial evaluation, an Orbscan II (Bausch & Lomb, Rochester, New York) corneal mapping topography was taken. The cornea of each patient was mapped to detect any irregularities or significant findings that could exclude the patient from completing the study. No Orbscan determinations were taken during the monovision trial evaluations.

Statistical Analysis

Statistical analysis of the results was performed using Microsoft Access 2003 and Excel 2003 for Windows (Microsoft, Redmond, Washington). Results were expressed as mean ± standard deviation. Results were calculated from the logarithms in the cases of visual acuity, contrast sensitivity, and spatial frequency, but the results were expressed in the original units. Statistically significant differences between data sample means were determined by using the paired *t* test (using the logarithms when applicable). A P value ≤ .05 was considered statistically significant.

Statistical analysis was performed on the error in each patient's measurements when there was a meaningful definition of error. For example, a +0.75 contact lens could be expected to change the wavefront refraction by –0.75 D. The error would be the amount the actual value differed from the expected value. Linear regression analysis was performed whenever there were results that could possibly change as a function of the increasing contact powers. Results were expressed as an equation with its coefficient of determination (R^2) and overall fit P value.

RESULTS

Fifty patients entered the study, and 49 completed the monovision contact lens trial in which one eye was treated with increasing powers of monovision lenses, 1 week for each power (treated eye), and the fellow eye received no treatment (untreated eye). One patient completed the trial with the +0.75 D and +1.50 D lens but could not tolerate the +2.50 D lens.

Before treatment, the treated eyes had a mean SE of 0.02 D ± 0.30, with a range of +0.75 D to –0.50 D, and a mean cylinder of –0.16 D ± 0.26, with a range of 0.0 to –0.75 (Table 1). In the untreated eyes, the mean SE was 0.05 D ± 0.34, with a range of +0.75 D to –0.75 D, and the mean cylinder was –0.15 D ± 0.24, with a range of 0.0 to –1.00 D. The mean pretreatment UCDVA of the 50 patients was logMAR –0.02 ± 0.12, Snellen equivalent 20/19 in the treated eye; and logMAR –0.09 ± 0.10, Snellen equivalent 20/16 binocularly (OU). The mean UCNVA was logMAR 0.66 ± 0.18, Snellen equivalent 20/92 in the treated eye; and logMAR 0.61 ± 0.14, Snellen equivalent 20/81 binocularly.

Table 2 shows some responses to questionnaires regarding pretreatment distance and near vision. Before treatment, when patients were asked the percentage of time they wore spectacles for near vision, the median response was 50%. For contacts for near vision, the median was 0%. When asked the percentage of time no correction was worn, the median was 30%. In response to the sentence, "My near vision is excellent without glasses," the median response value was 10 (scale: 0 = strongly agree, 10 = strongly disagree). Seventy-four percent had worn reading glasses for the past 4 to 5 years and 26% for the past 1 to 4 years. A total of 11 of 50 (22%) had previously tried monovision lenses. Thirteen of the 50 (26%) were wearing a +1.00 to +1.25 D correction, 16 of 50 (32%) were wearing a +1.50 to +1.75 D correction, and 10 of 50 (20%) were wearing a correction of +2.00 D or greater, with the remainder unsure of their reading power. Ten of the 50 (20%) wore bifocal spectacles all or some of the time because of the inconvenience of having to find reading glasses. Further spectacle-related questions pretreatment are in Table 3. Patients found wearing reading glasses very inconvenient, rating it a median value of 9 on a scale of 0 to 10, with 0 being "no inconvenience" and 10 being "extremely inconvenient."

TABLE 1. DEMOGRAPHIC AND PRETREATMENT INFORMATION OF PATIENTS PARTICIPATING IN MONOVISION CONTACT LENS STUDY

VARIABLE	TREATED EYES* N=50	UNTREATED EYES† N=50	BINOCULAR (OU)
Mean age (years) ± SD	55.4 ± 4.3		
Range	50 to 66 years		
Mean sphere ±SD	0.10 D ± 0.33	0.13 D ± 0.33	
Range	+0.75 to -0.50 D	+0.75 to -0.75 D	
Mean cylinder ±SD	-0.16 D ± 0.26	-0.15 D ± 0.24	
Range	0 to -0.75 D	0 to -1.00 D	
Mean sph. equivalent ±SD	0.02 D ± 0.30	0.05 D ± 0.34	
Range	0.75 to -0.50 D	0.75 to -0.75 D	
Uncorrected distance visual acuity			
Mean logMAR ±SD	-0.02 ± 0.12	-0.01 ± 0.08	-0.09 ± 0.10
Mean Snellen ±SD	20/19 (20/±5)	20/19 (20/±4)	20/16 (20/±4)
Range	20/60 – 20/12.5	20/30 – 20/12.5	20/30 – 20/10
Uncorrected near visual acuity			
Mean logMAR ±SD	0.66 ± 0.18	0.66 ± 0.15	0.61 ± 0.15
Mean Snellen ±SD	20/92 (20/±41)	20/91 (20/±32)	20/81 (20/±29)
Range	20/200 – 20/40	20/200 – 20/40	20/200 – 20/40
Best-corrected visual acuity			
Mean logMAR ±SD	-0.09 ± 0.08	-0.10 ± 0.08	
Mean Snellen ±SD	20/17 (20/±3)	20/16 (20/±3)	
Range	20/20 – 20/10	20/20 – 20/10	

SD = standard deviation.
*Eyes that were treated with increasing powers of monovision lenses.
†Fellow eyes that were not treated with increasing powers of monovision lenses.

TABLE 2. PATIENT QUESTIONNAIRE: DISTANCE AND NEAR QUALITY OF VISION PRETREATMENT

QUESTIONS ON DISTANCE VISION	FOR DISTANCE (N=50)	QUESTIONS ON NEAR VISION	FOR NEAR (N=50)
Spectacles (% of time you wear)		Spectacles (% of time you wear)	
Median (range)	0% (0-100)	Median (range)	50% (0-100)
CL (% of time you wear)		CL (% of time wear)	
Median (range)	0% (0- 20)	Median (range)	0% (0-100)
Neither (% of time you wear)		Neither (% of time wear)	
Median (range)	100% (0-100)	Median (range)	30% (0-100)
My distance vision without spectacles is excellent (0=strongly agree; 10 = strongly disagree)		My near vision without spectacles is excellent (0=strongly agree; 10 = strongly disagree)	
Median (range)	1 (0- 10)	Median (range)	10 (2- 10)
My distance vision with spectacles is excellent (0=strongly agree; 10 = strongly disagree)		My near vision with add spectacles is excellent (0=strongly agree; 10 = strongly disagree)	
Median (range)	10 (0- 10)	Median (range)	2 (0- 10)

CL = contact lenses.

TABLE 3. PATIENT QUESTIONNAIRE: PRETREATMENT SPECTACLE-RELATED QUESTIONS	
QUESTION	**GROUP RESPONSE**
Percent of daily tasks completed without near spectacles	
Median (range)	45% (0-100)
Years of wearing reading spectacles	
Median (range)	4 (1-5)
Convenience of using reading spectacles 0 = no inconvenience; 10 = extremely inconvenient	
Median (range)	9 (3-10)
Type of current reading spectacles	
Over-the-counter	20/50 (40%)
Prescription	30/50 (60%)
Cost of reading spectacles in past 5 years	
Over-the-counter (mean ± SD)	$116 ± 85
Prescription (mean ± SD)	$195 ± 86

SD = standard deviation.

EYE DOMINANCE

The eye dominance test described earlier was successfully applied to determine eye dominance in all 50 patients. The left eye was the nondominant eye in 36 of 50 (72%) of the patients. The trial lenses were placed on the nondominant eye of 50 of 50 patients. All patients had their nondominant eye as the treatment eye in this study.

Distance Visual Acuity

Mean logMAR UCDVA decreased in the treated eye with each increasing lens power, becoming worse than 20/80 with the +2.50 lens power (Figure 7). Binocular distance vision was essentially unchanged from pretreatment for the +0.75 D and the +1.50 D lens powers but showed a small decrease with the +2.50 power.

Subjective reports of excellent distance vision were highest at pretreatment and decreased with increasing monovision lens powers (Figure 8). There was a significant decrease in reported excellent distance vision with the +0.75 D (P <.01), +1.50 D (P < .01), and +2.50 D (P < .01) contact lenses.

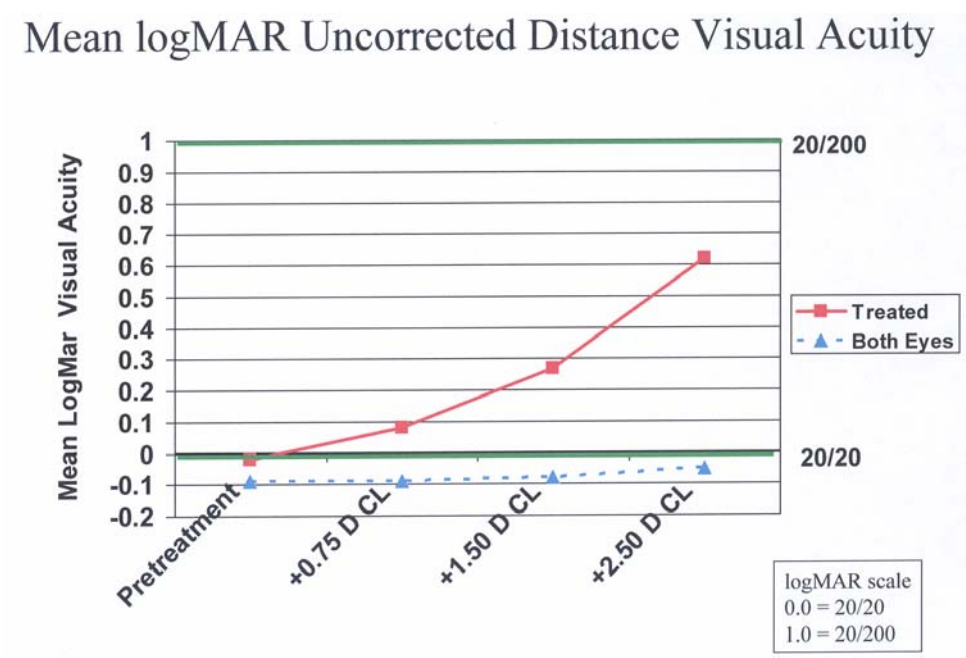

FIGURE 7

Mean logMAR uncorrected distance visual acuity for treated and untreated eyes at pretreatment and with the +0.75 D, +1.50 D, and +2.50 D contact lenses. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

Subjective responses to severity of specific visual problems under varying conditions are shown in Figures 9 through 12. Under all viewing conditions except viewing illuminated signs, problems with clarity of vision were the same or less severe with the +0.75 D lens power than at pretreatment (Figure 9) (P = .84). With powers higher than +0.75 D, however, severity of problems increased at +1.50 D (P = .78) and was highest and statistically significant with the +2.50 D lens (P <.01).

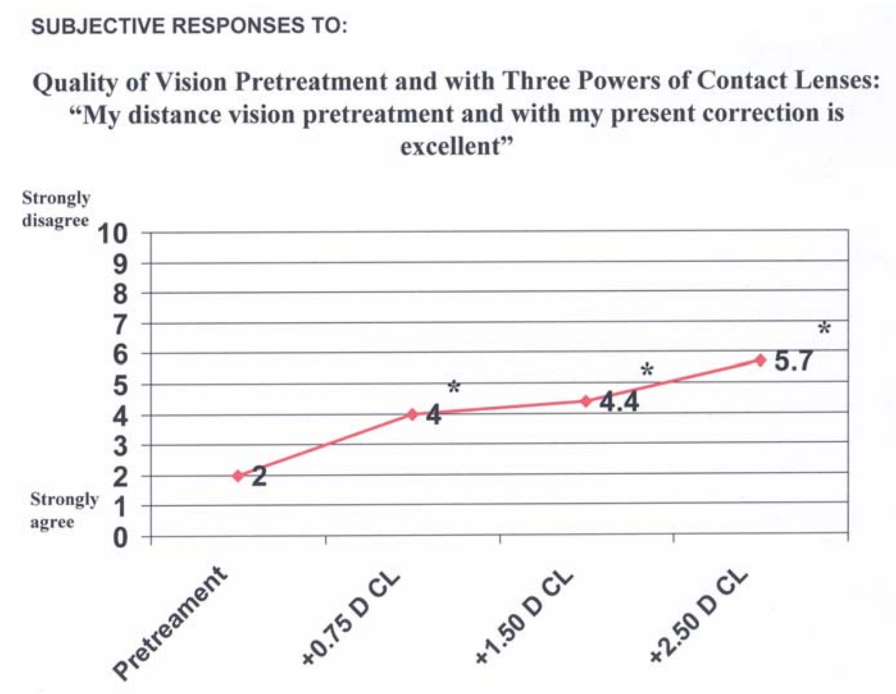

FIGURE 8

Quality of vision pretreatment and with three powers of contact lenses. Subjective response to question, "My distance vision pretreatment and with my present correction is excellent." Statistically significant changes from pretreatment shown with asterisk. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

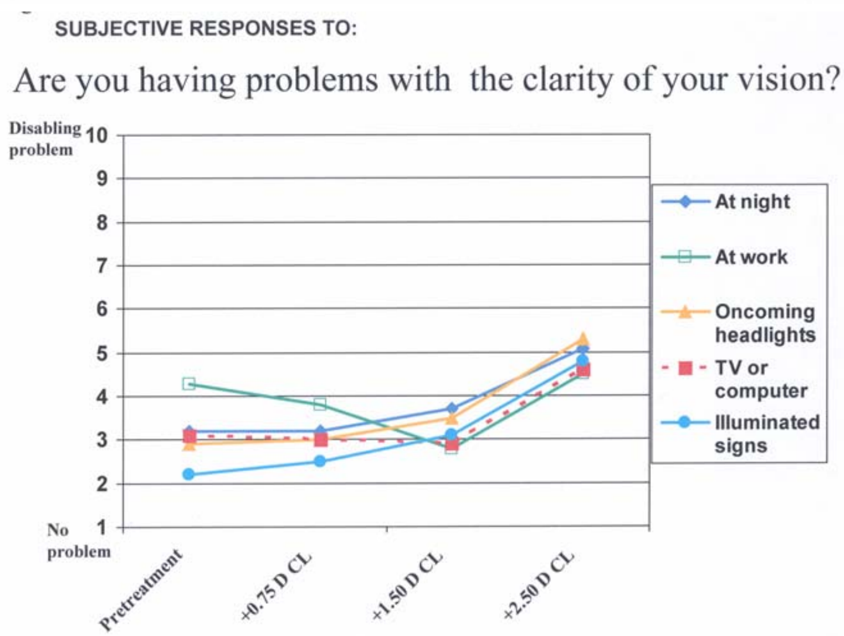

FIGURE 9

Subjective response to question, "Are you having problems with the clarity of your vision?" CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

For halos, rings, and starbursts (Figure 10), severity increased slightly from pretreatment with the +0.75 D lens for all the viewing conditions (P <.01). For lens powers greater than +0.75 D, severity of problems with halos, rings, and starbursts increased with the +1.50 D lens (P <.01) and was highest with the +2.50 D lens (P <.01).

For glare, problems decreased or remained at the same severity level with the +0.75 D lens (*P* = .20) and increased for the +1.50 D lens (*P* = .03), peaking with the +2.50 D lens (*P* < .01) (Figure 11).

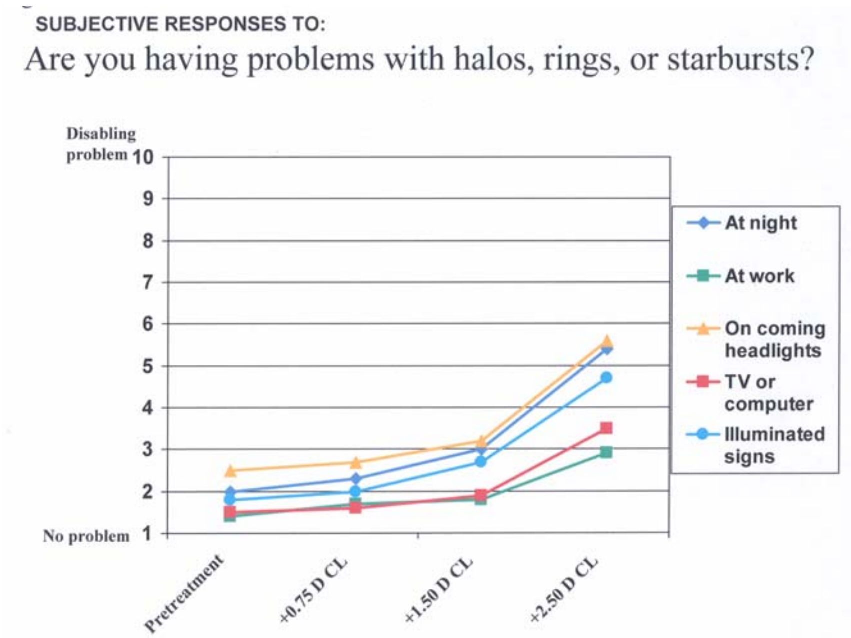

FIGURE 10

Subjective response to question, “Are you having problems with halos, rings, or starbursts?” CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N =49 for +2.50 D lens).

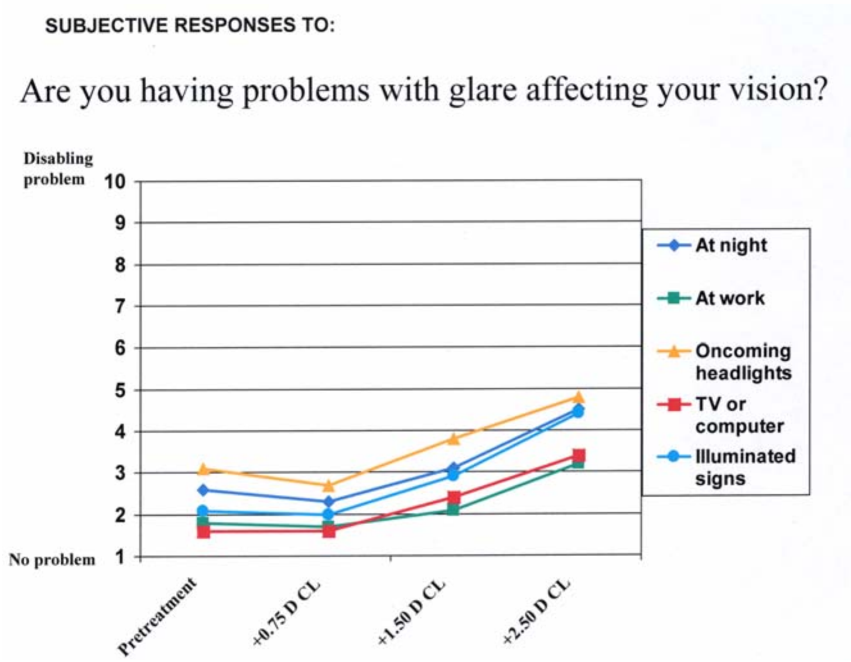

FIGURE 11

Subjective response to question, “Are you having problems with glare affecting your vision?” CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

For haze (Figure 12), severity of problems increased from pretreatment level with all lens powers under all viewing conditions. The severity was highest with the +2.50 D lens (*P* < .01 for every power).

NEAR VISUAL ACUITY

As monovision lens power was increased, there was a corresponding significant increase in mean UCNVA in the treated eye (*P* < .01 at each contact lens power) and in both eyes (binocularly) (*P* <.01 at each contact lens power) (Figure 13). Mean UCNVA in the treated eye improved from logMAR 0.66 ± 0.18 (Snellen 20/92) at pretreatment to logMAR 0.45 ± 0.23 (Snellen 20/56) with the +0.75 D contact lens. With the +1.50 D lens, UCNVA was logMAR 0.29 ± 0.16 (Snellen 20/39), and with the +2.50 D lens, logMAR 0.11 ± 0.19 (Snellen 20/26). Binocular values were parallel to treated-eye values.

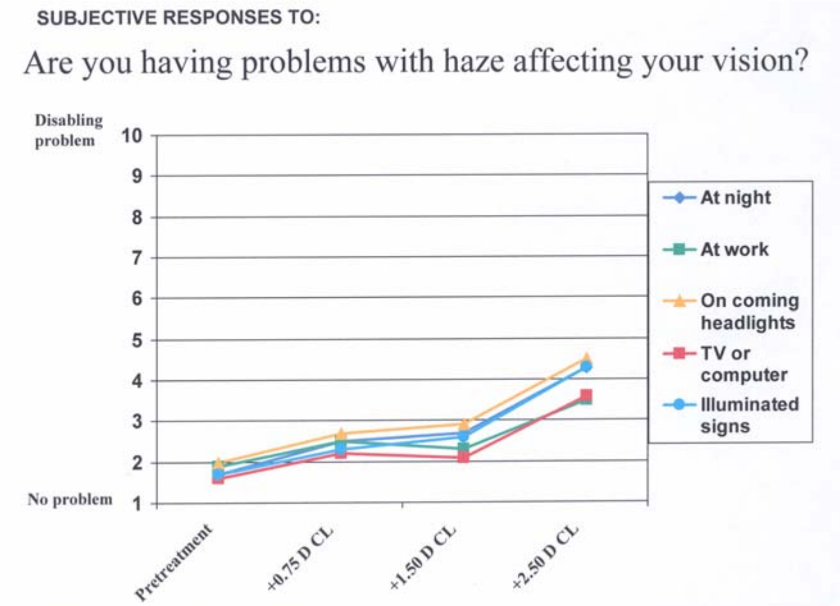

FIGURE 12

Subjective response to question, "Are you having problems with haze affecting your vision?" CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

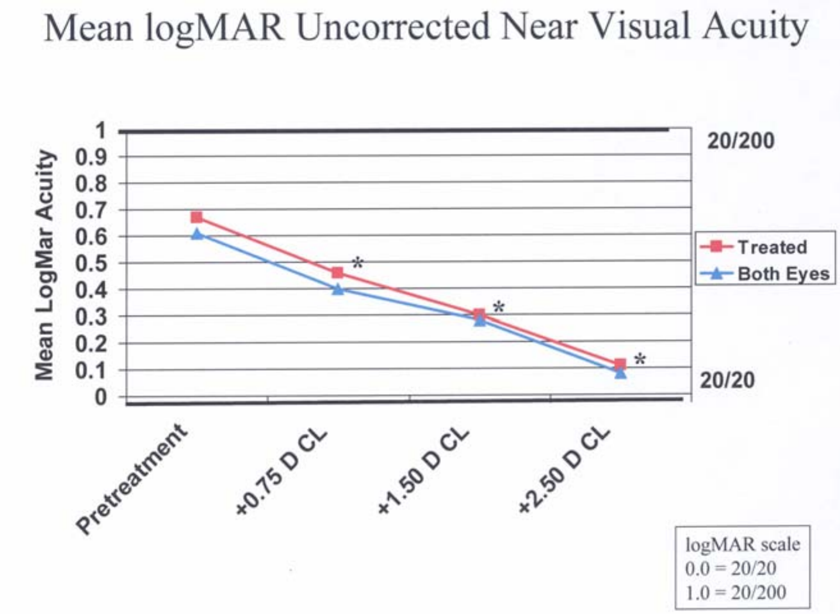

FIGURE 13

Mean uncorrected near visual acuity (logMAR) for treated and untreated eyes at pretreatment and with the +0.75 D, +1.50 D, and +2.50 D contact lenses. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

Subjectively, reports of excellent uncorrected near vision were better than at pretreatment with increasing lens powers, although there was no improvement in the +2.50 D contact lens over the +1.50 D contact lens. These improvements were significant (P <.01 at each lens power). The average value did not exceed 4.5 on a scale of 0 to10, reflecting subjects' perception of whether their vision with the contact lens was excellent (Figure 14).

The percent of daily tasks that could be completed without near add spectacles increased with each increasing lens power (Figure 15). Pretreatment was reported at 46%, and increased to 55%, 79%, and 82% for the +0.75 D, +1.50 D, and +2.50 D contact lenses, respectively. Note again the minimal gain in the +2.50 D contact over the +1.50. All the increases were statistically significant (P = .04, P <.01, and P <.01, respectively).

STEREOPSIS

At the initial evaluation, with no correction in place, mean distance stereopsis was 32 ± 23 seconds of arc (Figure 16). Mean distance stereopsis became worse with increasing powers of contact lenses. It decreased 27% to 44 ± 38 seconds of arc at the +0.75 D lens power (P < .01). It decreased 58% from pretreatment to 77 ± 76 seconds of arc at the +1.50 D lens power (P <.01). It decreased still further from pretreatment (82%) to 182 ± 142 seconds of arc at the +2.50 D lens power (P <.01). Note that there is more than just a marginal decrease in the +2.50 D contact lens over the +1.50 D contact lens.

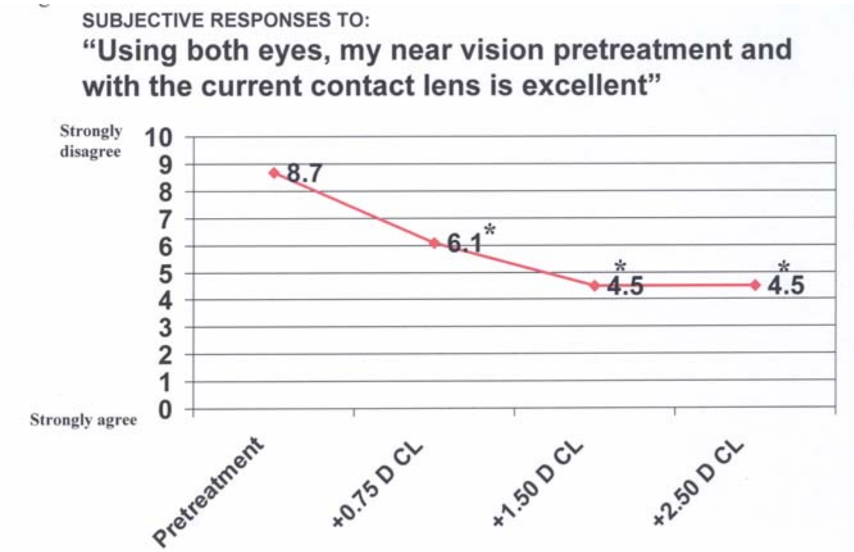

FIGURE 14

Subjective response to question, "Using both eyes, my near vision pretreatment and with the current contact lens is excellent?" Statistically significant changes from pretreatment shown with asterisk. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

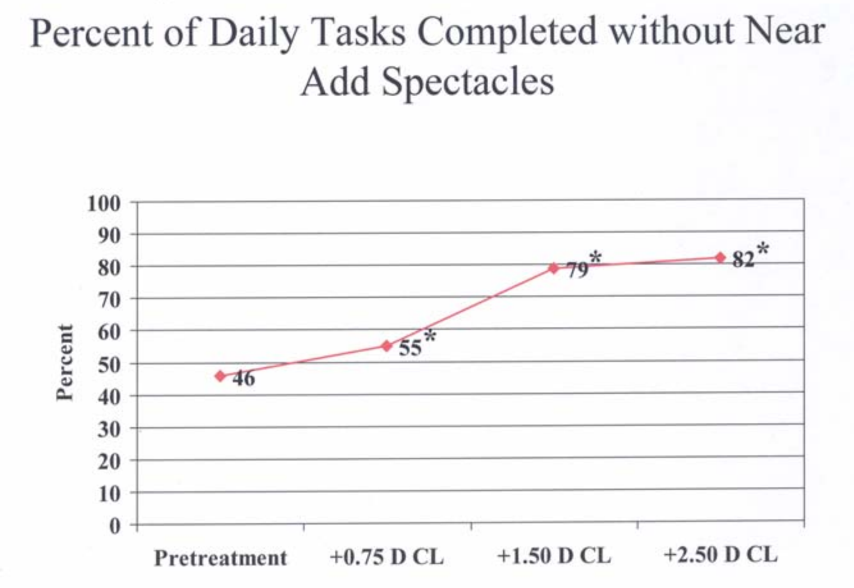

FIGURE 15

Percent of daily tasks completed without near add spectacles. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

CONTRAST SENSITIVITY

Photopic distance contrast sensitivity decreased with the progressive increase in monovision contact lens power in the treated eyes (Figure 17). At the lowest spatial frequency of 1.5 cycles per degree (cpd), contrast sensitivity did not vary significantly from pretreatment with the +0.75 D and the +1.50 D lens powers, but dropped significantly with the +2.50 D power (–28%, $P < .01$). At spatial frequencies 3 through 12 cpd, contrast sensitivity decreased significantly with increasing lens powers and reached a low with the +2.50 D lens power (a 71% decrease at 6 cpd). All P values were statistically significant (highest $P = .02$) for each spatial frequency and contact lens power. At the highest spatial frequency of 18 cpd, contrast sensitivity decreased with increasing lens powers and was significant at the +1.50 D lens power (–36%, $P < .01$) and the +2.50 D lens power (–51%, $P < .01$).

With all of the increasing lens powers, photopic contrast sensitivity values were lower than those of the patients' pretreatment value (except a statistically nonsignificant increase of 4% at 3 cpd with the +0.75 D lens). All percent changes from pretreatment value in photopic distance contrast sensitivity for the treated eye were statistically significant, with two exceptions: the +0.75 D and the +1.50 D lenses at 1.5 cpd and the +0.75 D lens at 18 cpd (Figure 18).

Mesopic distance contrast sensitivity decreased dramatically with the progressive increase in monovision contact lens power in the treated eye with the lowest values apparent with the +2.50 lens power (Figures 19 and 20). Every spatial frequency with each contact power showed a decrease. The decreases were significant in every case (highest significant $P = .02$) except at 1.5 cpd with the +0.75 D and +1.50 D lenses. The significant decreases ranged from –22% to –68%.

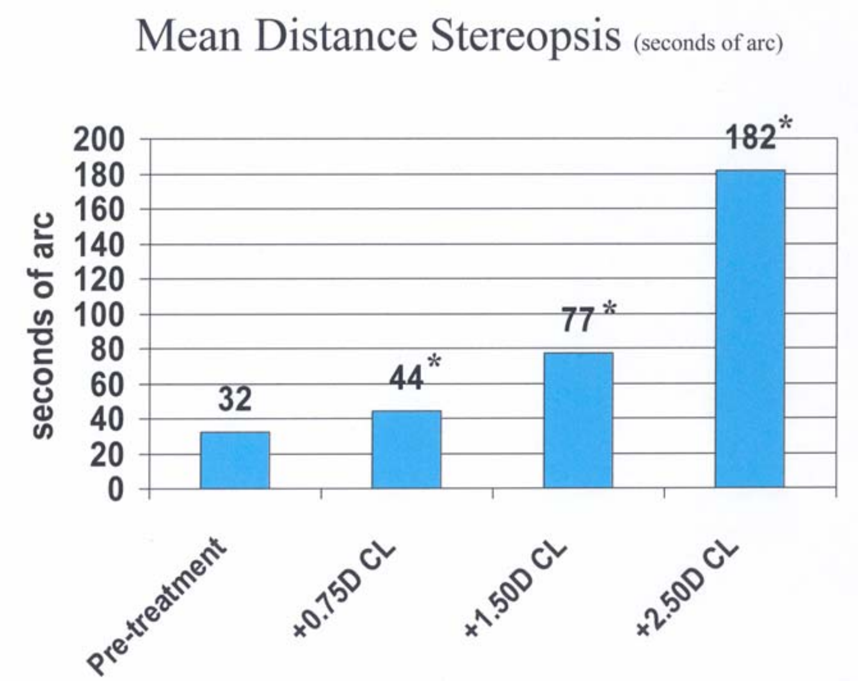

FIGURE 16

Mean distance stereopsis (seconds of arc) with the change in monovision power. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens).

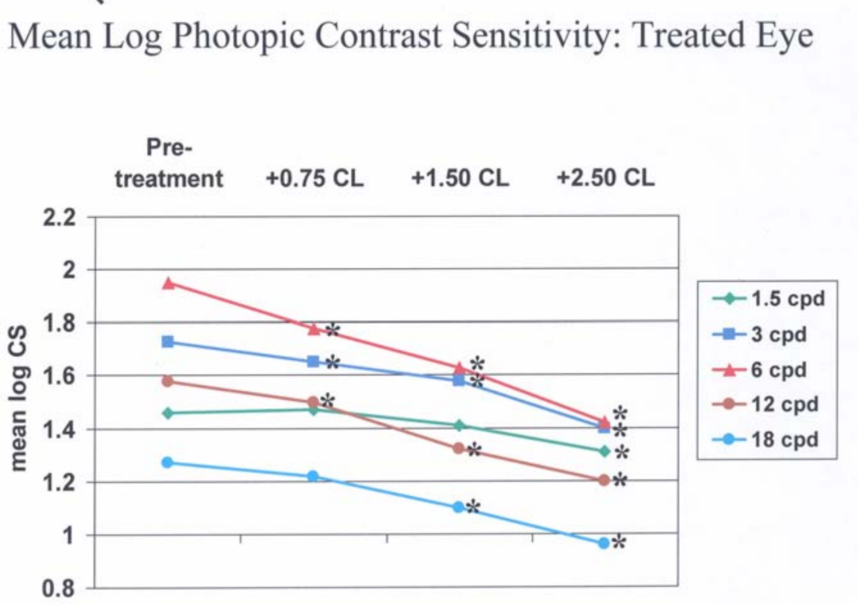

FIGURE 17

Mean log photopic contrast sensitivity (CS): treated eye. Pretreatment and with increasing power of monovision contact lenses. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens)

Binocular photopic distance contrast sensitivity did not vary much with increase in monovision contact lens power at any spatial frequency (Figures 21 and 22). No univariate *P* value was significant (lowest univariate *P* = .31). Multivariate analysis using Hotelling's T^2-test also yielded no significant *P* value at each contact lens power (lowest *P* = .54). Similarly, binocular mesopic distance contrast sensitivity did not vary much with increase in monovision contact lens power at any spatial frequency (Figures 23 and 24). The only significant *P* value was at 6 cpd with a +0.75 D lens (13% decrease, *P* = .05). Here multivariate analysis did result in one unexpected significant *P* value at the weakest contact lens power, +0.75 D (*P* = .05).

The *untreated* eye showed an increase in both the mesopic and photopic distance contrast sensitivity throughout all of the lens trials (except mesopic at 12 cpd with a +0.75 D lens, and photopic at 18 cpd with a +0.75 D lens). None of the univariate *P* values was significant. However, multivariate analysis resulted in one significant *P* value for increases in photopic contrast sensitivity with the +2.50 D lens (*P* = .01).

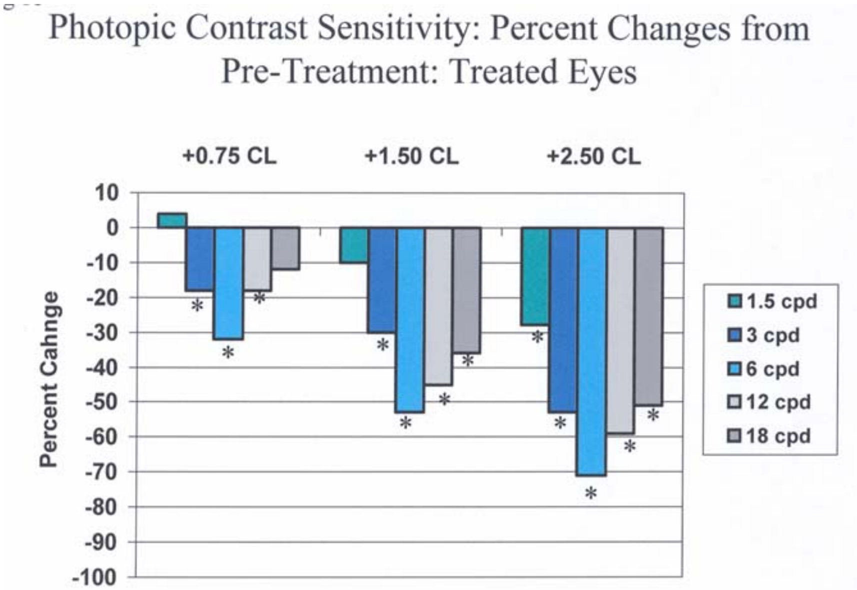

FIGURE 18

Photopic contrast sensitivity: percent change from pretreatment: treated eyes. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

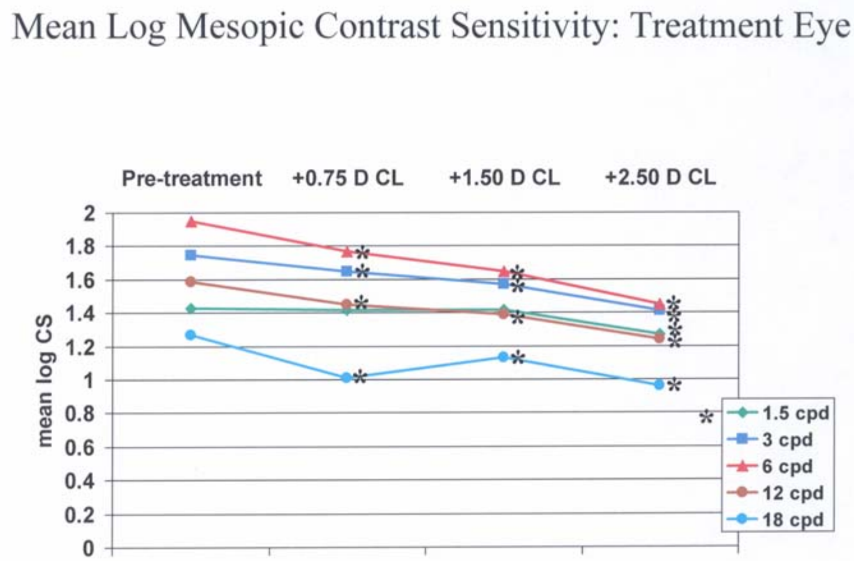

FIGURE 19

Mean log mesopic contrast sensitivity (CS): treatment eye. Pretreatment and with increasing power of monovision contact lenses. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens)

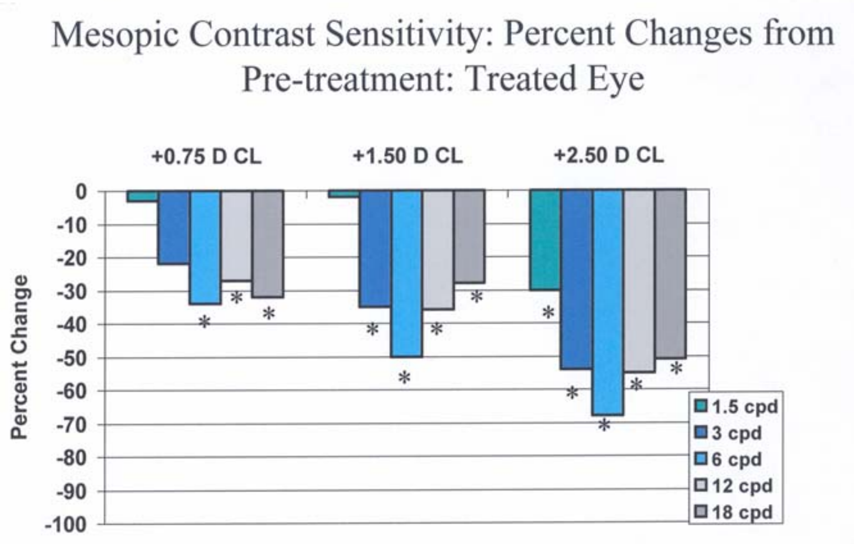

FIGURE 20

Mesopic contrast sensitivity: percent change from pretreatment: Treated eyes. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

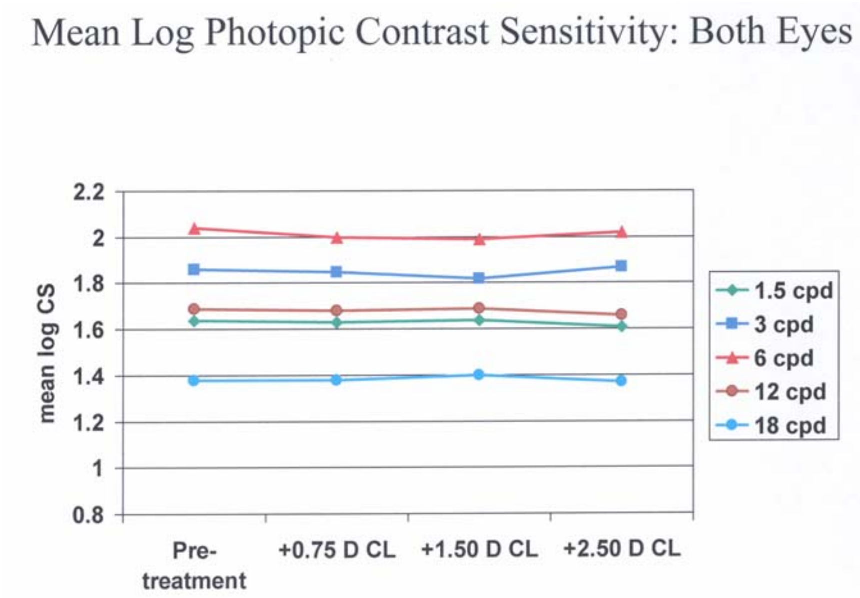

FIGURE 21

Mean log photopic contrast sensitivity (CS): both eyes. Pretreatment and with increasing power of monovision contact lenses. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens)

VISUAL FUNCTION WITH MONOVISION LENS POWERS

The ability to read newspaper headlines (Figure 25) showed a slight improvement from pretreatment with the +0.75 D and the +1.50 D lens powers (86% of patients pretreatment to 91% at +0.75 D and 95% at +1.50 D), and then decreased with the +2.50 D lens power (to 93%). Only the percentage of patients for the +1.50 D lens was significantly different from pretreatment ($P = .02$).

The ability to see the automobile dashboard (Figure 26) was reported by 88% of patients pretreatment, and improved to 98% with the +0.75 D lens power, then decreased slightly with the +1.50 and +2.50 D lens powers to 95% and 93% of patients, respectively. Only the percentage for the +0.75 D lens was significantly better ($P = .02$).

The ability to see the computer screen (Figure 27) improved from the pretreatment value of 40% of patients. It was reported by 57% while wearing the +0.75 D lens and by 84% while wearing the +1.50 D lens, but the improvement was lower at 74% while wearing the +2.50 D lens power. Every P value was significant (highest $P < .01$).

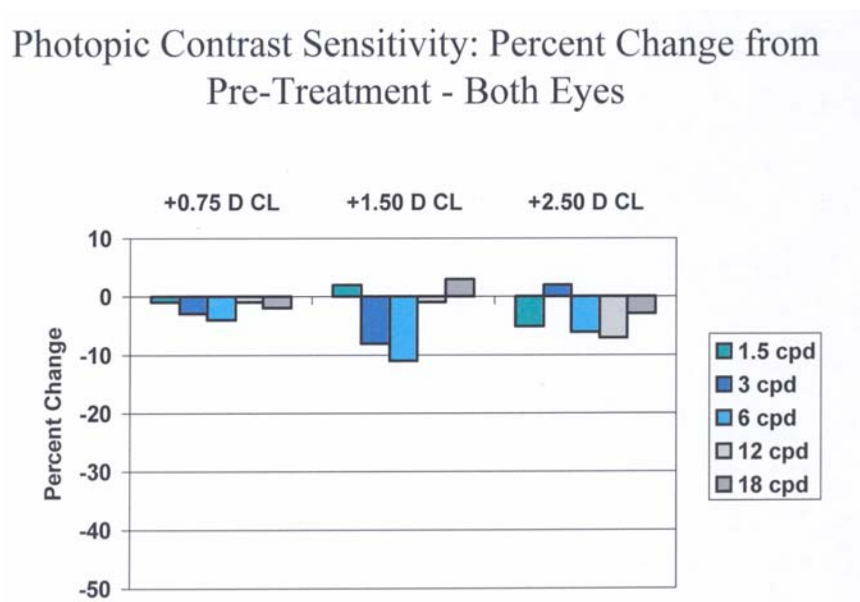

FIGURE 22

Photopic contrast sensitivity: percent change from pretreatment: Both eyes. CL = contact lens; cpd = cycles per degree. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens). No decreases from pretreatment are statistically significant.

The patients' ability to see their watch (Figure 28) improved from pretreatment with all of the lens powers. The percentage rose from 26% pretreatment to 60%, 77%, and 87% with increasing lens powers. Every P value was significant ($P < .01$).

The patients' ability to see their cellular phone (Figure 29) improved sharply from pretreatment (16%) with the +0.75 D (45%) and the +1.50 D (72%) lens powers, and then flattened out somewhat with the +2.50 D (80%) lens power. Every P value was significant (highest $P < .01$).

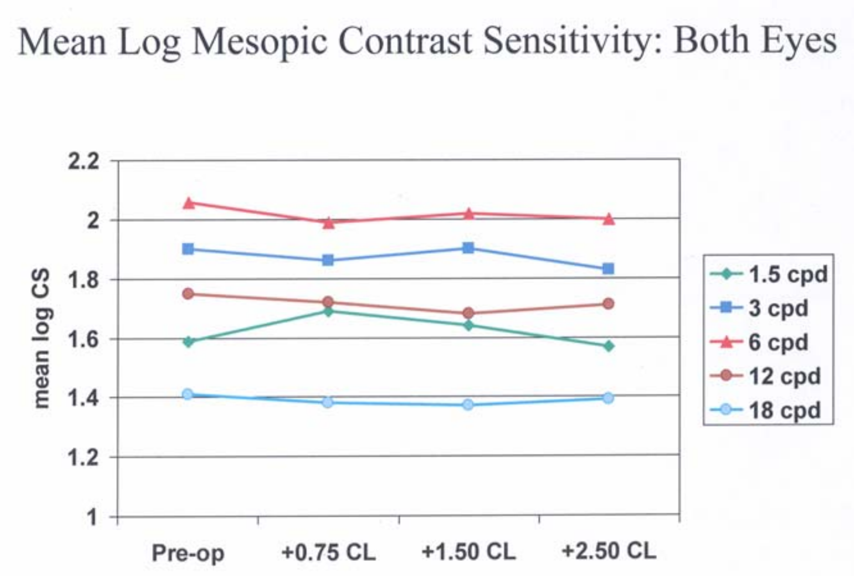

FIGURE 23

Mean log mesopic contrast sensitivity (CS): both eyes. Pretreatment and with increasing power of monovision contact lenses. CL = contact lens; cpd = cycles per degree. (N = 50 for pretreatment, +0.75 D, and +1.50 D lenses; N = 49 for +2.50 D lens)

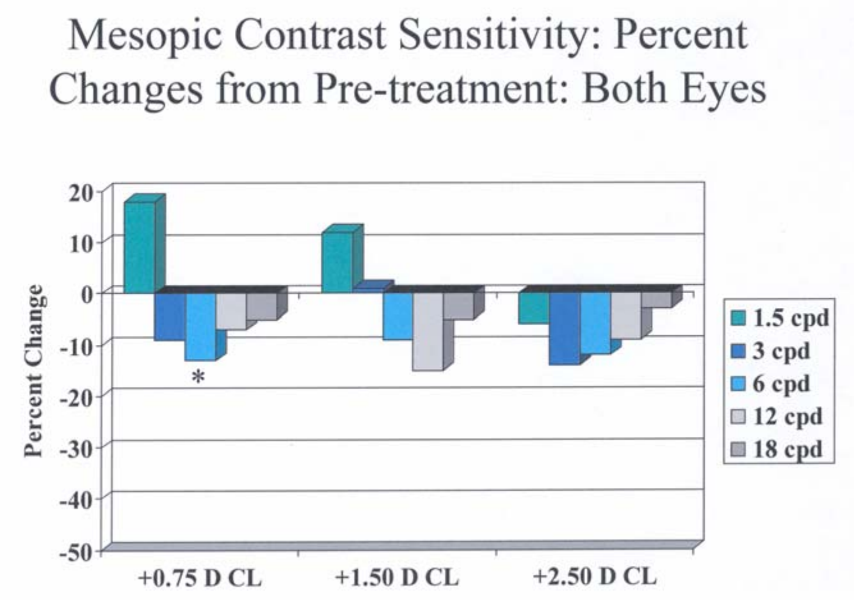

FIGURE 24

Mesopic contrast sensitivity: percent change from pretreatment: treated eyes. Statistically significant change from pretreatment shown with asterisk. CL = contact lens; cpd = cycles per degree. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

The patients' ability to see their medicine bottle label (Figure 30) improved from pretreatment as the lens powers increased, from 2% pretreatment, to 19%, 56%, and 74%. Again, every *P* value was significant (highest $P < .01$).

For the responses to the statement, "My ability to judge distances is excellent," the mean values (based on 0 = strongly agree, 10 = strongly disagree) were 1.7 pretreatment, 3.1 with the +0.75 D lens, 2.9 with the +1.25 D lens, and 5.1 with the +2.50 D lens (Figure 31). Every *P* value was significant (highest $P = .01$).

WAVEFRONT ERROR ANALYSIS

Wavefront Refraction Spherical Equivalent

An average error of +0.25 D more hyperopia than expected was found for each wavefront measurement over a contact lens (Table 4). The error was present regardless of the device used or the contact power, except for the Visual Function Analyzer by Tracey measurement at the +2.50 power, which showed an average error of +0.10 more hyperopia than expected. All *P* values were significant ($P <.05$), except for the Visual Function Analyzer by Tracey measurements at the +2.50 power ($P = .43$ for 6.0-mm pupil and $P = .51$ for 3.0-mm pupil).

In each case, linear regression analysis showed virtually no slope (average of –0.06 D of SE per diopter of contact power) with poor R^2 values (highest $R^2 = 0.01$) and poor fit *P* values (lowest $P = .23$). For this reason the average (constant) error of +0.25 D mentioned previously was considered a better descriptor of the error associated with wavefront measurements over a contact lens.

There was poor agreement between devices on the measurements obtained, with or without a contact lens, in either actual or expected power. This difference was significant ($P < .0001$ in every case). However, there was no significant difference ($P > .05$)

between devices on the calculated error (actual minus expected), except for the Alcon vs. the Visual Function Analyzer by Tracey measurements at the +2.50 D contact power ($P < .01$ and $P = .03$) (Table 5).

Because there was a large difference in mean values between most of the measurements and the Tracey 6.0 at 2.50 D and the Tracey 3.0 at 2.50 D, several additional analyses were performed comparing the other measurements with these two. This additional analysis did not result in any new statistically significant *P* values at the 95% level. Only the Alcon vs. the Tracey 3.0 and 6.0 at 2.50 D mentioned above were significant.

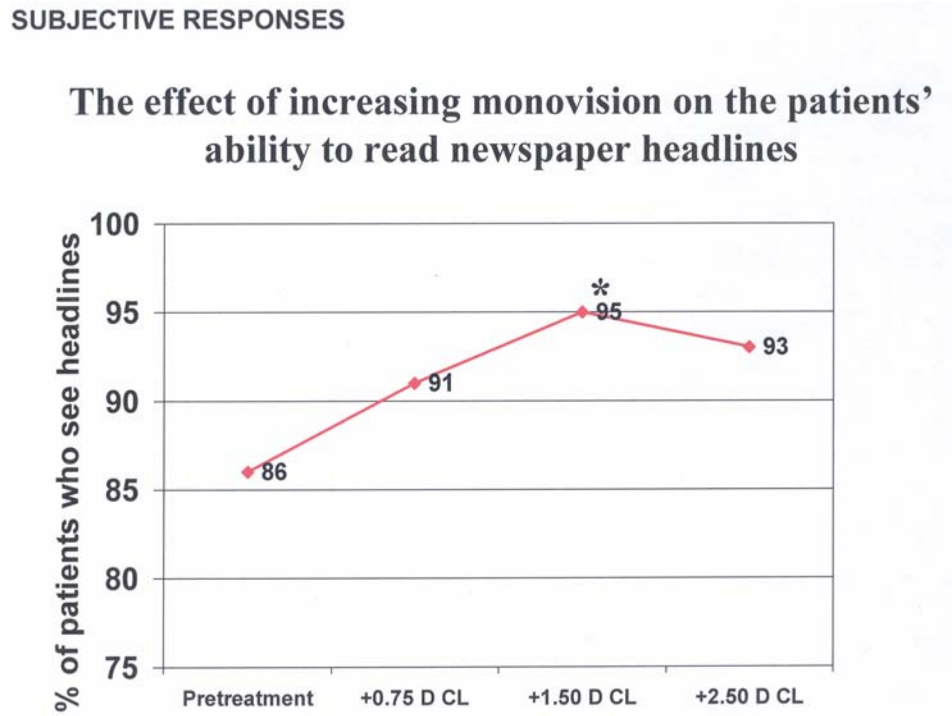

FIGURE 25

Subjective responses. The effect of increasing monovision on the patients' ability to read newspaper headlines. Statistically significant change from pretreatment shown with asterisk. CL = contact lens. (N=50 for +0.75 D and +1.50 D lenses; N=49 for +2.50 D lens)

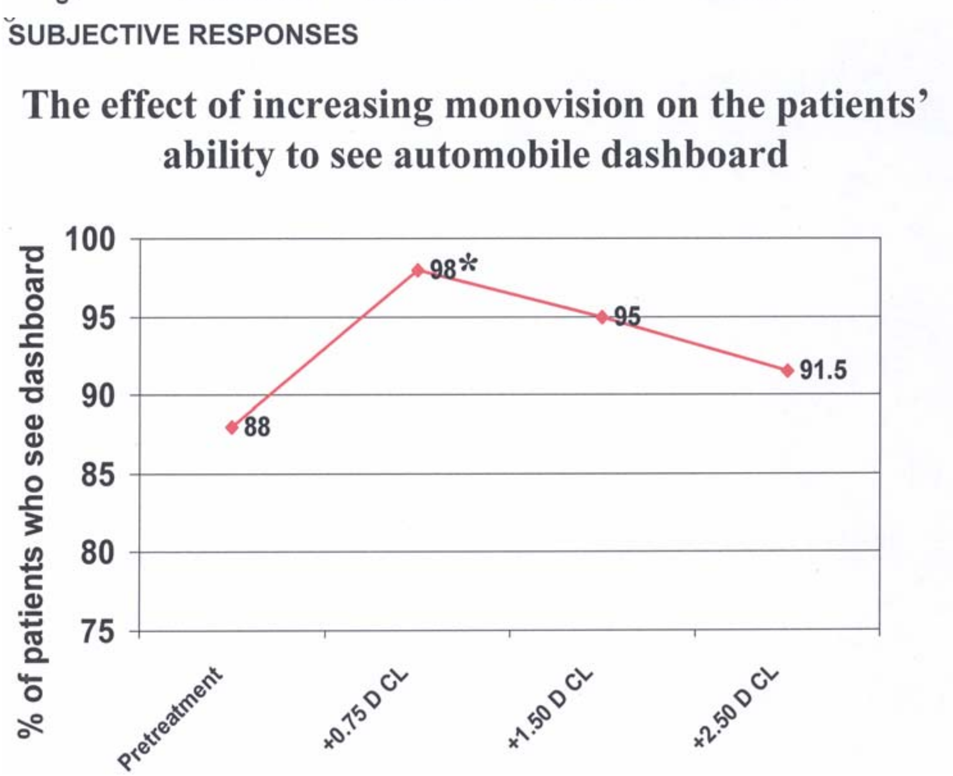

FIGURE 26

Subjective responses. The effect of increasing monovision on the patients' ability to see automobile dashboard. Statistically significant change from pretreatment shown with asterisk. CL = contact lens. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

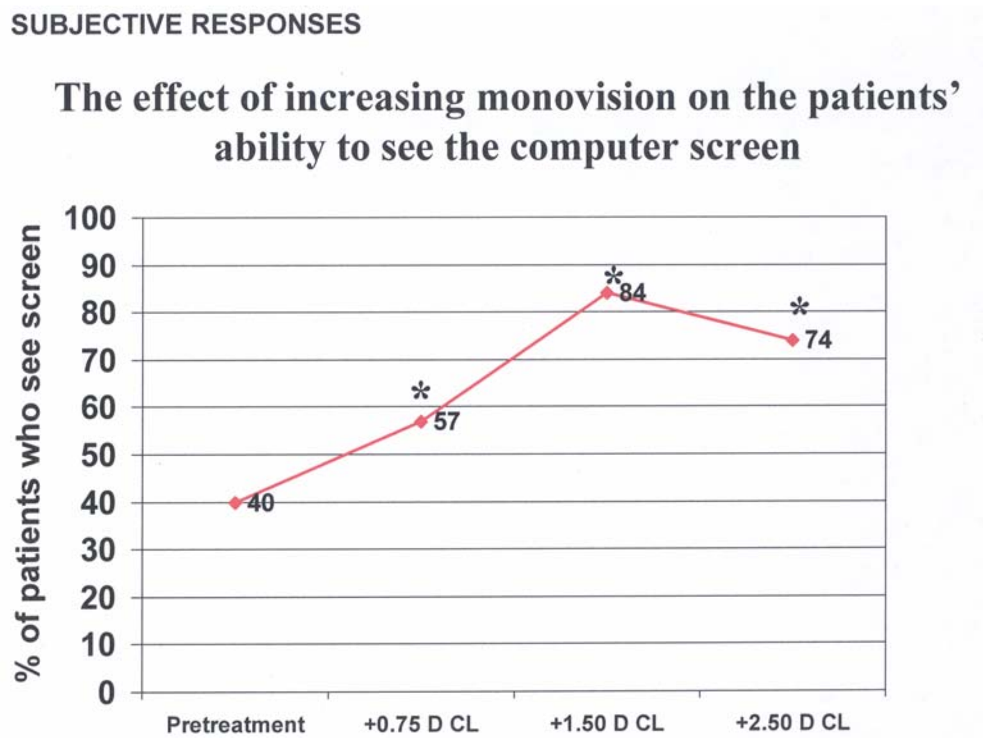

FIGURE 27

Subjective responses. The effect of increasing monovision on the patients' ability to see computer screen. CL = contact lens. Statistically significant changes shown from pretreatment with asterisk. N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

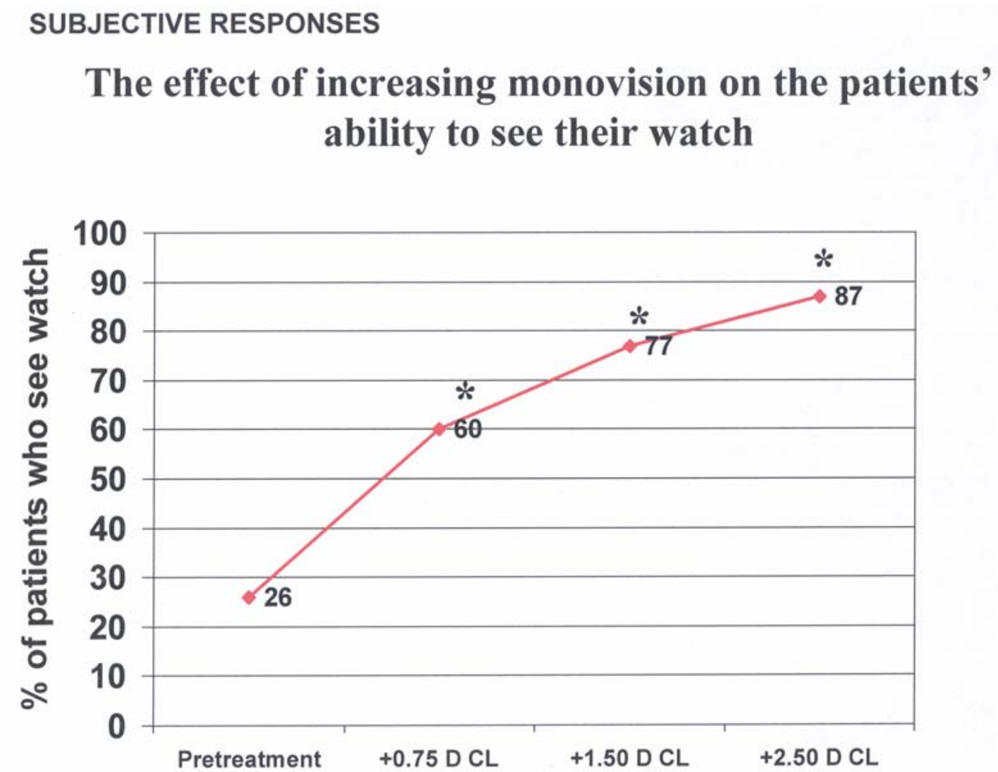

FIGURE 28

Subjective responses. The effect of increasing monovision on the patients' ability to see their watch. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

Wavefront Defocus Term

An average error of –0.56 more µm than expected (hyperopia) was found for each wavefront measurement over a contact lens with the Alcon aberrometer (6.5-mm pupil) (Table 6). (Note: A negative wavefront reading in microns corresponds with a positive prescription in diopters, and vice versa.) The error was defined as before. This error was significant at each contact lens power (highest *P* value was .0017 with the Alcon LADARWave device). The standard deviations were high at 0.85, 0.82, and 1.10 µm, respectively.

The Visual Function Analyzer by Tracey wavefronts at a 6-mm pupil had average errors of –0.38, –0.33, and –0.14 µm for measurements over a +0.75, +1.50, and +2.50 contact lens, respectively. The *P* values were .0025, .0071, and .43. The standard deviations were again high at 0.72, 0.75, and 1.05 µm. Similarly, the Visual Function Analyzer by Tracey wavefronts at a 3-mm pupil had average errors of –0.09, –0.06, and +0.01. The *P* values were 0.03, 0.10, and 0.43. The standard deviations were 0.23, 0.22, and 0.29 µm, respectively.

Linear regression analysis showed virtually no slope (average of 0.07 µm/D) with poor R^2 values (highest $R^2 = 0.004$) and poor fit *P* values (lowest $P = .08$). For this reason the average (constant) errors mentioned previously were considered better for describing the error associated with wavefront measurements over a contact lens, at least in the cases with a significant *P* value.

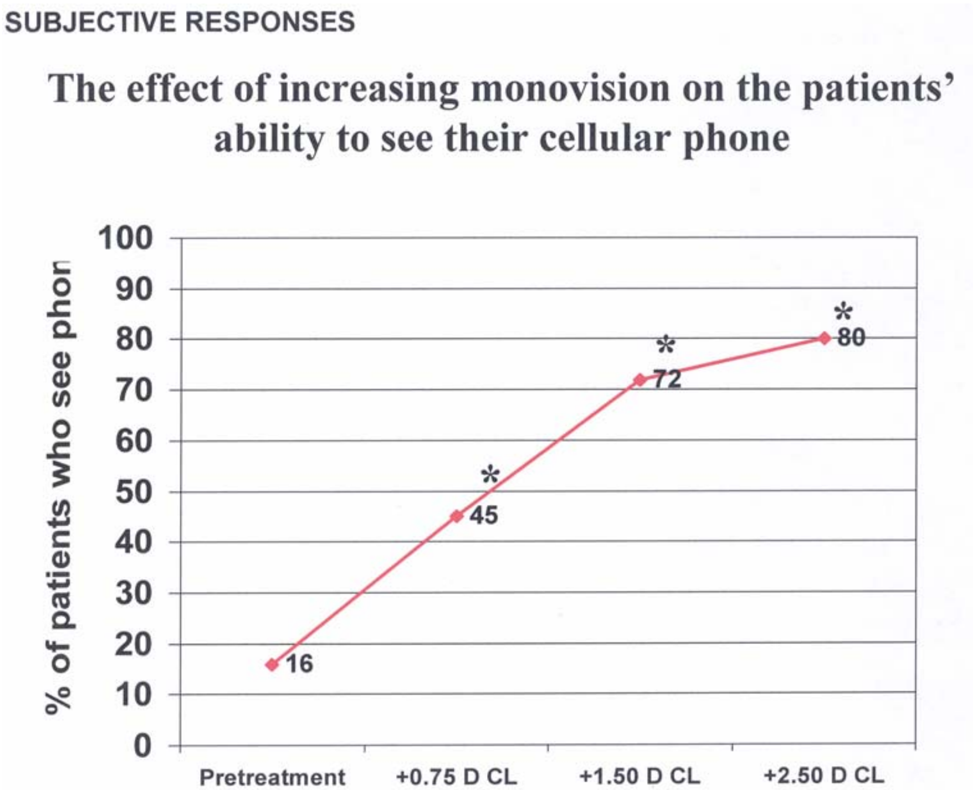

FIGURE 29

Subjective responses. The effect of increasing monovision on the patients' ability to see their cellular phone. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens).

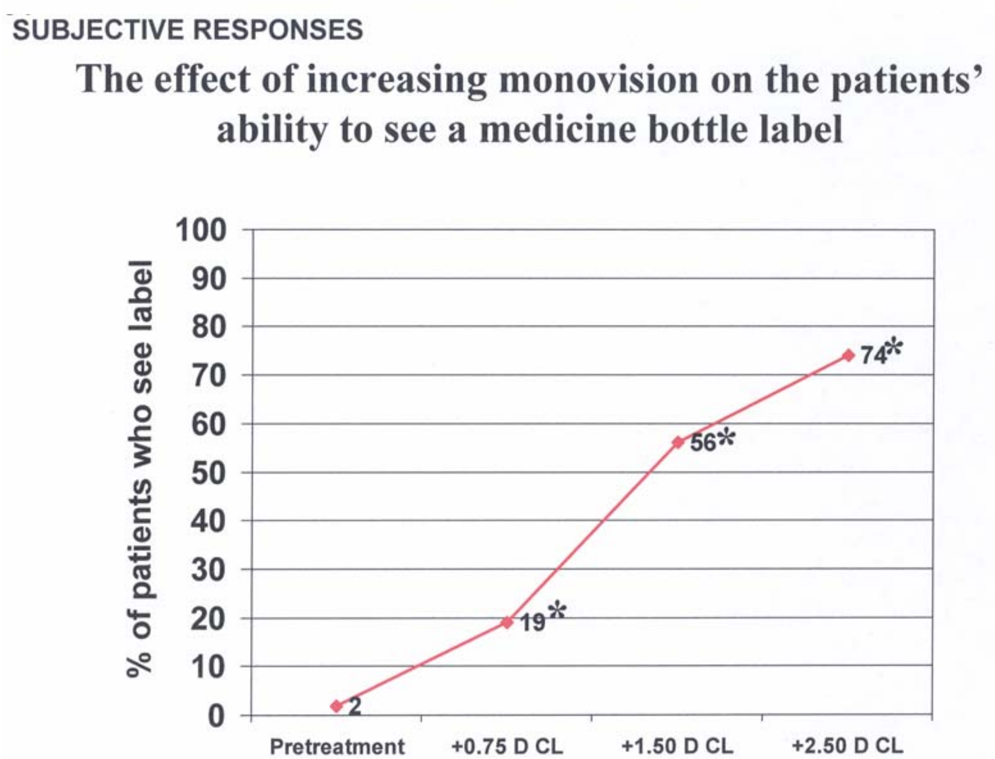

FIGURE 30

Subjective responses. The effect of increasing monovision on the patients' ability to see a medicine bottle label. Statistically significant changes from pretreatment shown with asterisk. CL = contact lens. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

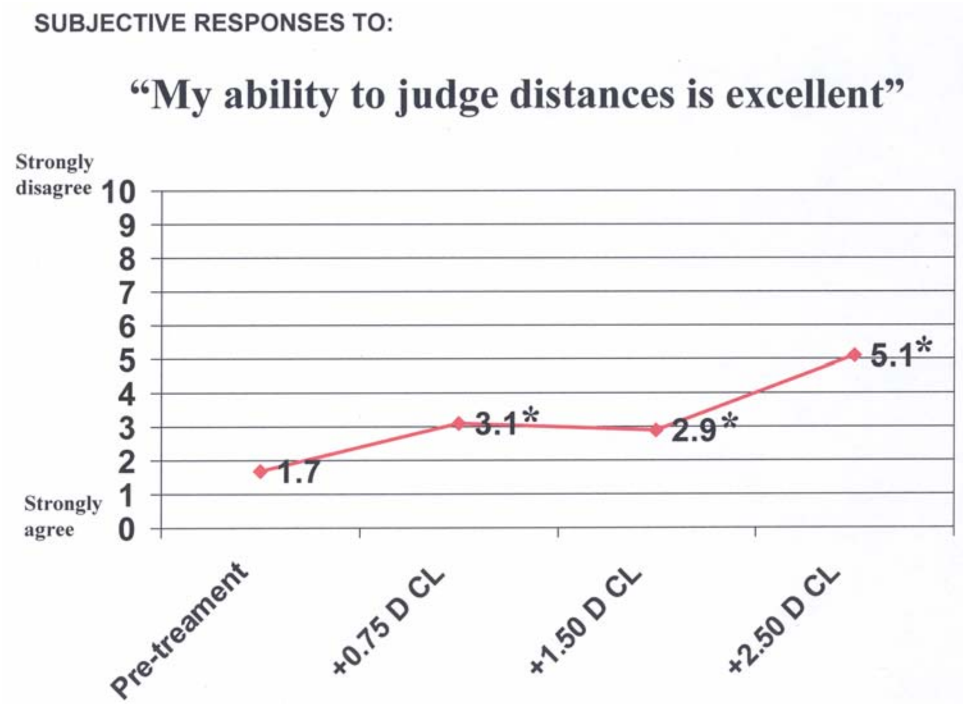

FIGURE 31

Subjective responses. "My ability to judge distances is excellent." Statistically significant changes from pretreatment shown with asterisk. CL = contact lens. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens)

Wavefront Spherical Aberration Term

In this case, linear regression analysis was significant (P = .02), resulting in the equation:

$$\mathbf{SA = -0.03 \times CL + 0.01}$$

for all devices (after rescaling for different pupil sizes), where SA is the spherical aberration in microns and CL is the contact lens power in D. The correlation coefficient^2 value was poor (R^2 = 0.02), reflecting the variability of measurements over contact lenses, but apparently there were enough patients to result in a statistically significant P value. The correlation coefficient^2 was the same for each device analyzed separately (R^2 = 0.02). Each equation's low coefficients (slope from 0.00 to –0.04 and constant 0.00 to 0.01) show that there is almost no change in the spherical aberration from wearing contact lenses, when measured by these aberrometers (Table 7).

TABLE 4. SPHERICAL EQUIVALENT ERROR BY WAVEFRONT DEVICE

LENS POWER	ALCON LADARWAVE ABERROMETER 6.5-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 6.0-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 3.0-MM PUPIL	
	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0
+0.75 D Lens	0.28 D (0.63)	.003*	0.28 D (0.55)	.003*	0.29 D (0.72)	.009*
+1.50 D Lens	0.32 D (0.56)	.0004*	0.27 D (0.62)	.009*	0.27 D (0.82)	.030*
+2.50 D Lens	0.32 D (0.74)	.004*	0.11 D (0.86)	.430	0.09 D (0.95)	.513

Mean of all mean error values (all 3 devices for all 3 lens powers) = 0.25 D.
SD = standard deviation.
*Statistically significant P values.
N = 50 eyes for +0.75 D and +1.50 D lens and N = 49 for +2.50 D lens.

Total Higher-Order Root Mean Square Changes

An average increase of 0.05 µm of total higher-order root mean square (RMS) was found for all the wavefront measurements collectively (Table 8). The averages for each device and contact lens power ranged from a 0.01 increase to a 0.11 increase, all of which are small changes (Figure 32). These were statistically significant changes (*P* ≤.05) in seven of nine cases. The standard deviations averaged approximately 0.14 µm.

TABLE 5. DEVICE COMPARISONS FOR SPHERICAL EQUIVALENT MEASUREMENT

ABERROMETER COMPARISON	*P* VALUE FOR CALCULATED ERROR (ACTUAL - EXPECTED)		
	+0.75 D LENS	+1.50 D LENS	+2.50 D LENS
Error with Tracey 6.0-mm pupil vs Error with Tracey 3.0-mm pupil	.382	.464	.556
Error with Alcon 6.5-mm pupil vs Error with Tracey 3.0-mm pupil	.962	.667	.008*
Error with Alcon 6.5-mm pupil vs Error with Tracey 6.0-mm pupil	0.802	0.853	.030*

*Statistically significant *P* values.
N = 50 eyes for +0.75 D and +1.50 D lens and N=49 for +2.50 D lens.

TABLE 6. WAVEFRONT DEFOCUS ERROR (N = 50 EYES)

LENS POWER	ALCON LADARWAVE ABERROMETER 6.5-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 6.0-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 3.0-MM PUPIL	
	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0
+0.75 D Lens	-0.54 µm (0.85)	<.0001*	-0.38 µm (0.72)	.003*	-0.09 µm (0.23)	.029*
+1.50 D Lens	-0.63 µm (0.82)	<.0001*	-0.33 µm (0.75)	.007*	-0.06 µm (0.22)	.099
+2.50 D Lens	-0.52 µm (1.10)	.002*	-0.14 µm (1.05)	0.430	+0.01 µm (0.29)	.787
Mean of mean errors (SD)	-0.56 µm (0.92)		-0.28 µm (0.84)		-0.05 µm (0.25)	

SD = standard deviation.
* Statistically significant *P* values.
N = 50 eyes for +0.75 D and +1.50 D lens and N=49 for +2.50 D lens.

TABLE 7. WAVEFRONT SPHERICAL ABERRATION ERROR (N = 50 EYES)

LENS POWER	ALCON LADARWAVE ABERROMETER 6.5-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 6.0-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 3.0-MM PUPIL	
	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0
+0.75 D Lens	-0.03 µm (0.15)	.141	-0.01 µm (0.16)	.667	0.00 µm (0.01)	.667
+1.50 D Lens	-0.06 µm (0.20)	.071	-0.03 µm (0.17)	.189	0.00 µm (0.01)	.189
+2.50 D Lens	-0.09 µm (0.18)	.001*	-0.06 µm (0.16)	.019*	0.00 µm (0.01)	.019*

SD = standard deviation.
*Statistically significant *P* values.
N = 50 eyes for +0.75 D and +1.50 D lens and N=49 for +2.50 D lens.

LENS POWER	ALCON LADARWAVE ABERROMETER 6.5-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 6.0-MM PUPIL		VISUAL FUNCTION ANALYZER BY TRACEY 3.0-MM PUPIL	
	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0	MEAN ERROR (SD)	*P* VALUE FOR ACTUAL MINUS EXPECTED = 0
+0.75 D Lens	0.04 µm (0.19)	.144	0.06 µm (0.16)	.161	0.01 µm (0.02)	.037*
+1.50 D Lens	0.06 µm (0.22)	.059	0.09 µm (0.18)	.003*	0.01 µm (0.02)	.134
+2.50 D Lens	0.11 µm (0.21)	<.001*	0.09 µm (0.24)	.020*	0.01 µm (0.03)	.040*

TABLE 8. WAVEFRONT TOTAL HIGHER-ORDER RMS ERROR (N = 50 EYES)

Mean of all Mean Error Values (all 3 devices for all 3 lens powers) = 0.05 µm.
SD = standard deviation.
*Statistically significant *P* values.
N = 50 eyes for +0.75 D and +1.50 D lens and N = 49 for +2.50 D lens.

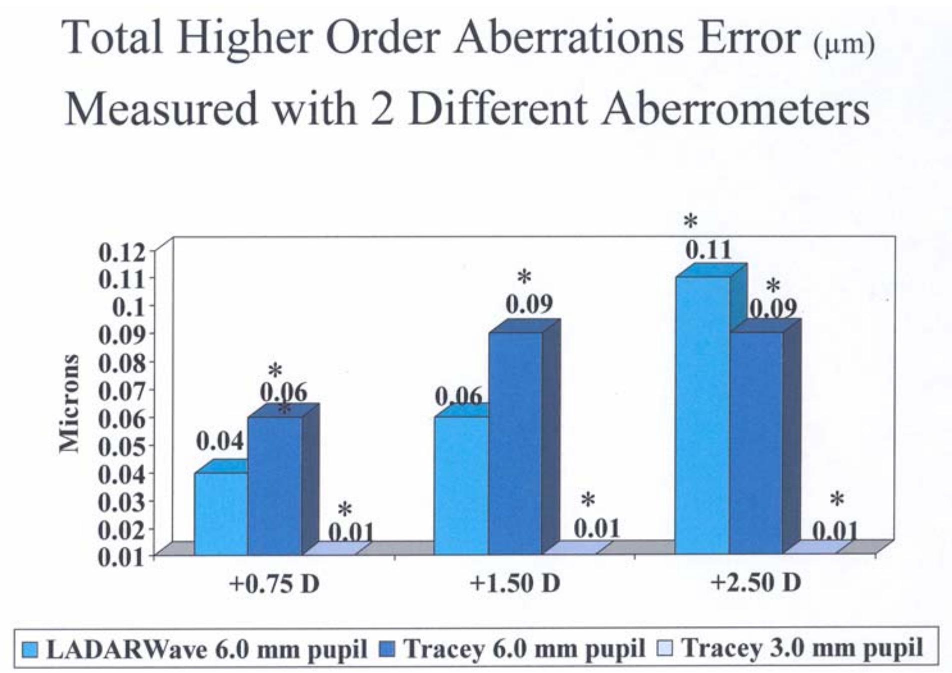

FIGURE 32

Total higher-order aberrations error (µm) for patients wearing three different powers of contact lenses; measured with the Alcon LadarWave aberrometer, 6.0-mm pupil; the Tracey Visual Function Analyzer, 6.0-mm pupil; and the Tracey Visual Function Analyzer, 3.0-mm pupil. (N = 50 for +0.75 D and +1.50 D lenses; N = 49 for +2.50 D lens). Statistically significant differences for actual minus expected shown with asterisk.

Linear regression analysis showed virtually no slope (average of 0.02 µm/D) with a poor correlation coefficent^2 value (R^2 = 0.01) and poor fit *P* value (*P* = .06). For this reason the average (constant) changes mentioned previously were considered better for describing the error associated with wavefront measurements over a contact lens, at least in the cases with a significant *P* value.

DISCUSSION

In this study, the goal was to study the effects of increasing monovision contact lens powers on emmetropic presbyopes, a population that enjoys good distance and near vision until the onset of presbyopia, to establish a reference standard for monovision contact lens performance and the performance after monovision surgical procedures. Emmetropic presbyopic patients are a large and growing segment of the US population and have lacked sufficient options for improving near vision. The 50 participating patients, ranging in age from 50 to 66 years, had all presented at the author's clinic seeking decreased dependence on reading glasses. Their spherical and cylindrical refractive error was low, placing them in the category of emmetropic presbyopes.

The study patients' binocular UCDVA was a mean of 20/16 and better than 20/30 in all cases, and none of them required any distance correction. Their binocular uncorrected near vision, however, was a mean of 20/81 (range, 20/40 to 20/200), which confirmed their emmetropic presbyopic condition. Furthermore, responding to the question, "My near vision is excellent without glasses," the median score was 10 out of a possible 10 (10 = strongly disagree). The median of the percentage of daily tasks they could perform without near spectacles was 45%. They found use of reading spectacles highly inconvenient, giving a median score of 9 for inconvenience (10 = extremely inconvenient).

Both objective and subjective (questionnaire) tests were performed on these patients at pretreatment and as they progressed through the monovision trial. To the author's knowledge, there are no reports in the literature comparing patient function with a monovision correction by both objective and subjective methods.

EYE DOMINANCE TESTING

Selection of a method to determine eye dominance was important in this study because patients of this particular presbyopic group have excellent uncorrected distance vision. This excellent distance vision is more likely to be preserved if the dominant eye is accurately identified.

Among the various tests that are used to determine eye dominance are (1) the hole-in-the-hand method, in which the patient sights a distance target in the gap between thumb and forefinger, (2) the plus lens test, in which a 1.5 D lens is placed in front of each eye in alternating fashion and the patient chooses the eye with the least amount of blur, (3) the camera-to-eye test, in which the patient, with distance correction in place, takes a camera and places it to the eye that he or she would normally use to take a photograph, (4) the near point of convergence test, (5) the refractive variance test, in which the more myopic eye is used for distance correction, and, occasionally, and (6) the handedness test, in which the right eye is designated for distance if the patient is right-handed.[28,29]

The method for testing eye dominance use in this study, the Interactive Eye Dominance Test, is unique in that both the doctor and the patient know which eye is dominant at the conclusion of the test. It is especially important for this group of patients to understand eye dominance because their success with a monovision contact lens will highly depend on their comprehension of how their eyes will work together and the effect it may have on their distance vision. The author has used many other eye dominance tests, and the patients did not seem to understand the process, the results, or the implications. With this method, the patient knows exactly what is being tested, the instructions are clear, the test is easy for the patient, and it can easily be repeated.

In this study, the Interactive Eye Dominance Test was successfully used to identify the dominant eye in all 50 patients, and the monovision trials were conducted on the nondominant eye in all of the patients. One patient of the 50 could not tolerate the +2.50 D lens.

There is evidence, however, that the convention of correcting the dominant eye for distance can be broken. In early studies, Schor and associates[30,31] found that ability to suppress blur was not significantly affected by correcting the dominant or nondominant eye for near, and this finding was confirmed by Robboy and associates,[32] who found no difference in visual acuity when eye dominance was used to identify the near and the distance eye. Jain and associates[33] found that crossed monovision after excimer laser refractive monovision surgery could result in satisfactory visual outcomes.

Despite these reports, the nondominant sighted eye is typically chosen for near correction. The dominant eye is believed to be better suited for vector tasks, such as walking, running, or driving a car,[34] whereas the nondominant eye may be better suited for near tasks because these do not require a precise sense of absolute visual direction.[30] Furthermore, small-angle esophoric shift that monovision patients tend to have is reduced in magnitude when the dominant eye is corrected for distance.[35]

DISTANCE VISUAL ACUITY

Before treatment, the patients' mean refraction in the eye to be treated and the untreated eye were close to plano, and UCDVA in each eye, as well as binocularly, was excellent. After placement of the contact lenses on the treated eye, distance visual acuity decreased significantly, as expected. The amount of decrease corresponded with the power increase of the lens.

Binocular distance visual acuity remained virtually unchanged from pretreatment with increasing contact lens powers because the untreated dominant eye was able to suppress the blur signal from the treated eye and provide good vision binocularly. The retention of binocular distance vision with contact lens monovision is important for emmetropic patients because they have enjoyed excellent distance vision all of their life. Fear of losing distance vision is one of the principal barriers to these patient attempting any contact lens or surgical near vision improvement. This study shows that if the only vision tests performed were objective bilateral high-contrast acuity tests, the conclusion would be misleading to both doctors and patients. Despite the objective finding of unchanged binocular distance visual acuity, subjective reports of problems with distance vision in the patients' questionnaire responses showed dramatically increasing severity of problems with increasing contact lens powers, beginning with the +0.75 D lens power and peaking with the +2.50 D power (Figure 8).

SUBJECTIVE RESPONSES TO A VARIETY OF VIEWING CONDITIONS

The patients reported on problems with increasing monovision lens powers regarding clarity of vision; halos, rings, and starbursts; glare; and haze while performing everyday tasks. These tasks are related to a patient's contrast sensitivity function, which will be discussed later. The variety of visual conditions presented to the patients included near, intermediate, and far distances, as well as a variety of lighting conditions. These were not standardized, and the patient's response would have depended, for example, on whether their computer or television is at an optimal distance and whether lighting conditions at their workplace are optimal. Despite this, the mean response of 50 patients may present an accurate depiction of the prevalence of problems in contact lens–wearing patients under certain conditions.

The responses for these tasks were highly varied, but a few trends were apparent. Mean clarity of vision was the best with the +0.75 D power and the worst with the +2.50 D power. The mean rating for halos, rings, and starbursts with the +0.75 D lens was similar in severity to the pretreatment value, became worse with the+1.50 D lens, and was markedly worse with the +2.50 D lens. Glare and haze followed a similar pattern to that of halos, rings, and starbursts. Clearly, of the three lens powers tested, the +2.50 D lens power was the most problematic for patients under a variety of conditions.

NEAR VISUAL ACUITY

Before treatment, all patients had poor UCNVA, as expected in this group with an age range of 50 to 66 years. Their major complaint was an inability to see at near without some kind of correction, and this was reflected by their individual UCNVA values. Not surprisingly, the objective tests showed that the patients' ability to see at near significantly improved as monovision lens power was increased. Snellen mean UCNVA values improved from Snellen 20/101 at pretreatment to 20/65 ± 42 with the +0.75 D lens, 20/42 ± 15 with the +1.50 D and 20/29 ± 27 with the +2.50 D contact lenses. Binocular values were nearly identical to the treated eye values.

Subjectively, near vision was not improved with each increasing lens power, even though the objective tests of near vision showed improvement. The best mean near vision was with the +1.50 D lens. With the +0.75 D lens power, patients did not feel the lens was strong enough for them to function well at near. As the lenses increased in power, they could see better at near, but the problems at distance overpowered the benefits at near.

For successful adaptation to monovision, a patient should be able to suppress, to some degree, the blurred image from one eye so that it does not interfere with the image from the other eye. This is known as interocular blur suppression.[30,31,36] Successful monovision patients have been reported to have approximately 100 times greater interocular suppression of blur than the unsuccessful.[37,38] Given the near vision results in the patients in this study, it can be concluded that interocular blur suppression functioned to some extent in all of the patients with monovision lenses. With the higher-power contact lenses, inability to suppress the blur of the near eye for distance vision may have contributed to the subjective problems with distance vision.

DISTANCE STEREOPSIS

Reduced stereoacuity is considered to be the major disadvantage of monovision.[39-43] In the 12 publications examined by Jain and associates in their meta-analysis,[37] stereopsis in monovision ranged from 23 to 72 arc sec for distance and 50 to 113 arc sec for near. In this study, near stereoacuity under monovision decreased a mean of 37 arc sec (from 87 arc sec to 124 arc sec) compared with stereoacuity under binocular viewing conditions. The average normal value for stereopsis is 20 arc sec; for persons older than 40 years, it is 58 arc sec.[44]

In this study, mean distance stereopsis values were best at pretreatment and decreased with each increasing contact lens power. The decrease in distance stereopsis was small with the +0.75 D lens, moderate with the +1.50 D lens, but dramatically worse with the +2.50 D lens. This dramatic decrease corresponds with the patient's dissatisfaction with this amount of monovision correction. Although the literature shows monovision contact lens correction of presbyopia to reduce near stereoacuity, how could near stereopsis be tested when a presbyopic patient cannot see the near card during the test? The author believes near stereopsis testing is an inappropriate test for presbyopic patients.

CONTRAST SENSITIVITY

In this study, extensive contrast sensitivity tests were performed in the treated eye, untreated eye, and OU under both photopic (daylight) and mesopic (night) testing conditions. In the treated eyes, photopic contrast sensitivity for all frequencies was highest at pretreatment and decreased significantly with progressive increase in monovision contact lens power. At the lowest spatial frequency (1.5 cpd), the mean photopic contrast sensitivity values did not vary much from pretreatment with the +0.75 D lens power, but dropped from pretreatment with the +1.50 D and the +2.50 D power. With higher spatial frequencies (3 through 18 cpd), contrast sensitivity decreased as more blur was introduced with increasing lens powers and reached a low with the +2.50 D power. Most photopic contrast sensitivity percent changes from pretreatment with the three lens powers were statistically significant at all cpd. The untreated eyes showed some changes in mesopic and photopic contrast sensitivity throughout the lens trials that were not of any clinical significance.

Mesopic contrast sensitivity values also decreased markedly with increasing lens powers and were lower than pretreatment values for all spatial frequencies. With decreased levels of light and increased blur, poorer contrast vision is expected. These results correlate with the patients' reports of problems with clarity of vision under night conditions.

Binocularly, neither photopic nor mesopic contrast sensitivity varied much from pretreatment. The only significant *P* value was at the weakest contact lens power of +0.75 D mesopically. A significant decrease at this power alone was not expected and may reflect an adjustment period to having a contact lens on the eye. It could also be that a small difference between the eyes affects contrast more than a larger one. No other *P* value was significant. This was expected because the patient uses the untreated dominant eye to view a distance target. As was seen with binocular high-contrast acuity testing, the binocular eye data did not correlate well with the patients' subjective assessment of their vision. The decrease in contrast sensitivity in the treated eye was very significant to the patient, especially at the +2.50 D lens power, and contributed to their dissatisfaction with their overall correction.

The *untreated* eye showed a general increase in both photopic and mesopic contrast sensitivity with increasing lens powers, becoming significant with the +2.50 lens for photopic contrast sensitivity. This may reflect adaptation by the patient to compensate for the blur in the fellow eye. It may also reflect a learning curve to the test itself, as photopic contrast sensitivity with the +2.50 lens was the last contrast test given to the patient.

VISUAL FUNCTION WITH MONOVISION LENS POWERS

The +0.75 D contact lens power was rated best for seeing the automobile dashboard and the computer screen and television, all of which require good intermediate vision. The +1.50 D contact lens was rated best for the ability to see newspaper headlines. And finally, the +2.50 D contact lens power was best for seeing the cellular phone and the wrist watch. The best mean near vision was with the +1.50 D lens. With the +0.75 D lens power, patients did not feel the lens was strong enough for them to function well at near. As the lenses increased in power, they could see better at near, but the problems at distance overpowered the benefits at near.

WAVEFRONT ANALYSIS RESULTS

Very little information is available on how contact lenses affect the wavefront analysis of the eye. One of the goals of this study was to observe the effect of the different power lenses on the wavefront using two different types of wavefront sensors, Hartmann-Shack (Alcon LADARWave) and Ray Tracing (Tracey VFA). Were the decreases in contrast sensitivity, stereopsis, and subjective complaints of quality of vision related to an increase in higher-order aberration as has been seen in laser refractive surgery?

First, an attempt was made to determine the best descriptor for the error associated with wavefront measurements over a contact lens, including SE, defocus, and spherical aberration. Linear regression analysis showed that a constant value was the best descriptor for the SE and defocus terms. For the SE measurement, the constant was +0.25 D more hyperopia than expected for a wavefront measurement over a contact lens. This implies that wavefront refraction taken with a contact lens in place will measure +0.25 D more than the power of lens used for that patient. It is well known that a patient's refraction displayed by an aberrometer may not represent that patient's manifest refraction.[45-50] This is because the presence of significant higher-order aberrations in the eye influences the patient's manifest refraction. Therefore, the only notable finding in the SE analysis was that the wavefront reading over the contact lens shows a minimal constant error toward hyperopia (overcorrection).

Analysis of the wavefront defocus term also showed a consistent error in the hyperopic (overcorrection) direction over all contact lens powers for both aberrometers. For spherical aberration, the error seen with both aberrometers and with all lens powers was small. This implies that spherical aberration measured with a contact lens in place will not be very different from the spherical aberration value of a particular eye without the lens in place. This is important because an increase in spherical aberration causes decreased contrast sensitivity and subjective complaints such as halo and glare.[51] Spherical aberration did not change significantly with any power contact lens and can be ruled out as a significant factor in the diminished vision in these patients.

For higher-order RMS error, a very small average increase of 0.05 µm of total higher-order RMS (the constant) was seen, ranging from an increase of 0.01 µm with the Visual Function Analyzer by Tracey with all three lens powers to 0.11 µm with the Alcon LADARWave with the +2.50 D lens power. Again, increased higher-order aberrations were not seen with monovision contact lenses of any power and can also be ruled out as a cause of visual compromise.

LIMITATIONS AND POSSIBLE SOURCES OF BIAS IN THIS STUDY

Patients were asked to wear each lens power for 1 week before changing to the next-higher power. This period was shorter than the usual contact lens adaptation time and would not have allowed for long-term neural adaptation. Longer-term contact lens wear was not practical in this study because three powers of lenses were used. The 1-week period was chosen as sufficient for short-term adaptation but still practical for the subjects in the study.

The *P* value for statistical significance was set at .05. This means that 95% of the time, if a difference was detected by the statistical significance test, it would be a true difference. However, 5% of the time, a false difference would be found. A *P* value of <.05 is used most often, but a *P* value of <.01 would be more rigorous, so that a false difference would be found only 1% of the time. However, the chances of missing a true difference would increase. A sample size *much* larger than that in this study (50) would also give some greater assurance that only true differences would be detected.

In addition to limitations, there are several possible sources of bias in this study.

There is always a possibility that patients do not understand a question or questions in a questionnaire or inadvertently mark an unintended response on the scale for the question. The nature of the study and the questionnaire were explained in detail to all participating patients, and they were all willing participants. However, the author cannot be sure that all questions were answered as the patient intended.

A patient may have had the misperception that she or he had to perform well on the tests in order to receive refractive surgery. Alternatively, a patient may have wanted to do poorly in order to justify the need for refractive surgery. Some patients may have been able to subconsciously memorize some of the repeated tests. For example, contrast sensitivity was tested OD/OS/OU, both mesopically and photopically, each week for 3 consecutive weeks.

Dry eyes could have been a confounding factor for this study. Dry eyes, a windy day before the examination, a lengthy examination, and low humidity could all increase the amount of contact lens drying between blinks, thereby degrading vision. A previous experience with contacts, whether successful or not, could have affected the patients' responses. However, having some previous contact lens wearers in the study would reflect the fact of contact lens wearers in the general population.

The inclusion in this study of patients "presenting at our clinic seeking decreased dependence on reading glasses" could have possibly affected the generality of the results. First, our patients were all residents of the Midwestern United States. Weather conditions, including temperature, humidity, and wind, affect tolerance and acceptability of contact lenses. Weather conditions may have been different during each 1-week trial of different lens powers and thus may have affected the ability of patients to see at near or distance during the wearing of different lens powers during specific periods.

Additionally, patient occupation was not recorded but may have had an effect on reported results. A patient population composed of computer workers, engineers, and others who rely on near vision in their job might have had more stringent requirements for near and intermediate vision than persons in an occupation such as truck driving, in which retaining good distance vision would be more valued.

Also, patients who are seeking decreased dependence on reading glasses (most likely a surgical procedure) may view a contact lens correction of any lens power less favorably than presbyopic patients not seeking a surgical correction.

CONCLUSIONS

In this study, three different powers of contact lenses in 50 emmetropic presbyopic patients were analyzed to determine the objective results and subjective responses associated with wear of those lenses. The author believes these tests revealed that standard objective visual test results do not correlate with subjective results in monovision contact lens–wearing patients. In other words, as has been often seen after surgical procedures, the objective visual results may show good vision, but patients may be dissatisfied with their overall functional vision.

The results of the objective tests showed that monocular distance vision decreased with each increasing lens power, as expected, but that binocular distance vision on objective testing remained unchanged from pretreatment, likely on account of the interocular suppression of blur during the tests. Subjectively (binocularly), however, patients showed decline of distance vision with each increasing power. Distance stereopsis also decreased with each increasing lens power. This loss of binocular function may be responsible for part of the subjective vision loss.

For near vision, Snellen acuity improved with each increasing lens power. Subjectively, however, the +0.75 D lens power was not rated strong enough for near vision tasks, such as reading newspaper headlines.

The subjective binocular testing of vision under a variety of distances and lighting conditions showed that disability in performing tasks increased from pretreatment with increasing lens powers and significantly increased with the +2.50 D lens. Overall, the best near and intermediate vision was obtained with the +1.50 D lens power. These results show that monovision contact lens fitting in the presbyopic emmetropic population in a power greater than +1.50 D is not indicated for initial lens fitting. It is possible that after initial adaptation, stronger powers may be tolerated. Overall, this study showed that +1.50 D is the monovision correction "sweet spot" for the near vision eye.

Objective and subjective testing are required to demonstrate the outcome of a monovision contact lens fitting. In addition, the tests reported here need to be applied when evaluating near vision outcomes of surgical procedures to understand how patients will function in the "real world." As new surgical procedures are developed for the treatment of presbyopic vision loss, reported efficacy data need to include contrast sensitivity and stereopsis results, as well as a detailed evaluation of the patients' subjective visual function. It is anticipated that this study may serve as a guideline for evaluation of existing and new near vision enhancement surgical procedures.

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APPENDIX A

Analysis of increasing monovision on functional vision at near and distance
Initial Evaluation: Lifestyle questionnaire

Psychosocial and Visual Characteristics

DATE QUESTIONNAIRE COMPLETED: _____/____/____
Month Day Year

PATIENT'S NAME: ______________________ ____________________________ ____________
First **Last** **Last 4 SSN**

We are interested in finding out about your current vision, use of corrective lenses, your job, and your reasons for wanting to decrease dependability on reading glasses. We are interested in **your** opinions, ideas, and experiences. There are no right or wrong answers. All of the information you provide is confidential and will be published **only** in summary statistical form. You will not be identified in any way.

The information you give us will not affect your health care, or your vision care in any way.

In order to get accurate information about refractive surgeries and how they affect people's vision, we need information from **all** patients.

This questionnaire has 5 pages. If your copy does not have 5 pages, please contact the person administering the questionnaire.

PLEASE READ EACH QUESTION AND SELECT THE ANSWER THAT BEST REPRESENTS YOU.

1) These questions ask about your **current** use of corrective lenses for **DISTANCE VISION**. In answering these questions please think about your typical use of glasses and/or contact lenses during the **last 30 days**. While you are **AWAKE**, do you currently wear glasses or contact lenses in **either** eye to improve your eyesight at **DISTANCE**? Please indicate what percentage of the time you wear ***contact lenses, glasses or neither***.

PERCENT OF TIME WEAR **GLASSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **CONTACT LENSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **NEITHER** GLASSES **NOR** CONTACT LENSES

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

TOTAL of above 3 questions for DISTANCE VISION: 100%

2) My** DISTANCE VISION* without ***glasses is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

3) My** DISTANCE VISION* with ***glasses is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

4) These questions ask about your **current** use of corrective lenses for **NEAR VISION**. In answering these questions please think about your typical use of glasses and/or contact lenses during the **last 30 days**. While you are **AWAKE**, do you currently wear glasses or contact lenses in **either** eye to improve your eyesight at **NEAR**? Please indicate what percentage of the time you wear ***contact lenses, glasses or neither***.

PERCENT OF TIME WEAR **GLASSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **CONTACT LENSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **NEITHER** GLASSES **NOR** CONTACT LENSES

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

TOTAL of above 3 questions for NEAR VISION: 100%

5) My NEAR VISION ***with*** glasses is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

6) My NEAR VISION ***without*** glasses is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

7) What percentage of your daily tasks would you be able to complete ***without*** your reading glasses

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

8) If you are ***without*** your reading glasses which of the following items are you be able to see? (please circle)

A) Newspaper Headline
B) Dashboard
C) Computer screen
D) Watch
E) Cellular phone
F) Medicine bottle label

9) How many years ago did you begin to wear reading glasses at least part-time?

1) 1-2years ago 2) 2-3 years ago 3) 3-4 years ago 4) 5-6 years ago

10) What is the inconvenience of having to put on reading glasses to see objects up close?

No Inconvenience Extremely Inconvenient

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

11) Have you ever tried any type of monovision in the past?

1) Yes 2) No

11 a) If ***YES*** rate the success of your monovision trial?

Not Successful Very successful

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

12) Are your current glasses

1) Over the counter 2) Prescription

13) Approximately how much have you spent on reading glasses in the last 5 years?

1) $0-50 2) $50-100 3) $100-200 4) more than $200

14) What is the power of your current reading glasses?

1) +1.00 - +1.50 2) +1.50-+2.00 3) greater than +2.00 4) unsure

15) People have different experiences with their vision. Some people have problems with **sharpness** or **clarity** where the edges seem fuzzy or indistinct. Please indicate whether you now—that is within the **last two weeks**—have problems with **sharpness** or **clarity** in any of the following situations.

On a scale of 1 to 10, where **1** stands for **"no problems"** and **10** stands for **"disabling problems,"** how much trouble do you have with **sharpness or clarity:**

CLARITY	**No Problems**	**Disabling Problems**
A. At night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
B. During work?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
C. From oncoming car headlights at night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
D. When watching television or using a computer monitor?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
E. When reading a brightly illuminated road sign at night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	

PLEASE CONTINUE TO THE NEXT PAGE

16) People have different experiences with their vision. Some people have problems with **halos, rings** or **starbursts** around objects or lights. Please indicate whether you now—hat is within the **last two weeks**—have problems with **halos, rings** or **starbursts** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **"no halos"** and **10** stands for **"disabling halos,"** how much trouble do you have with **halos:**

HALOS	**No Halos**									**Disabling Halos**
A. At night?	1.	2.	3.	4.	5.	6.	7.	8.	9.	10
B. During work?	1.	2.	3.	4.	5.	6.	7.	8.	9.	10
C. From oncoming car headlights at night? . .	1.	2.	3.	4.	5.	6.	7.	8.	9.	10
D. When watching television or using a computer monitor?	1.	2.	3.	4.	5.	6.	7.	8.	9.	10
E. When reading a brightly illuminated road sign at night?	1.	2.	3.	4.	5.	6.	7.	8.	9.	10

17) People have different experiences with their vision. Some people have problems with **glare** or **light sensitivity**. Please indicate whether you now—that is within the **last two weeks**—have problems with **glare** or **light sensitivity** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **"no glare"** and **10** stands for **"disabling glare,"** how much trouble do you have with **glare:**

GLARE	**No Glare**									**Disabling Glare**
A. At night?	1. . . .	2. . . .	3. . . .	4. . . .	5. . . .	6. . . .	7. . . .	8. . . .	9. . . .	10
B. During work?	1. . . .	2. . . .	3. . . .	4. . . .	5. . . .	6. . . .	7. . . .	8. . . .	9. . . .	10
C. From oncoming car headlights at night?	1. . . .	2. . . .	3. . . .	4. . . .	5. . . .	6. . . .	7. . . .	8. . . .	9. . . .	10
D. When watching television or using a computer monitor?	1. . . .	2. . . .	3. . . .	4. . . .	5. . . .	6. . . .	7. . . .	8. . . .	9. . . .	10
E. When reading a brightly illuminated road sign at night?	1. . . .	2. . . .	3. . . .	4. . . .	5. . . .	6. . . .	7. . . .	8. . . .	9. . . .	10

18. People have different experiences with their vision. Some people have problems with **hazy** or **foggy vision**. Please indicate whether you now—that is within the **last two weeks**—have problems with **hazy** or **foggy vision** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **“no haze”** and **10** stands for **“disabling haze,”** how much trouble do you have with **haze:**

HAZE	**No Haze** … **Disabling Haze**
A. At night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . 10
B. During work?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10
C. From oncoming car headlights at night? . .	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10
D. When watching television or using a computer monitor?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10
E. When reading a brightly illuminated road sign at night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10

19) My ability to judge distances is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…..

20) How important is it for you to be able to perform near tasks ***without*** reading glasses?

Not Important Extremely Important
0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

APPENDIX B

<u>Analysis of increasing monovision on functional vision at near and distance</u>
Assessment of functional vision with use of monovision contact lens

Psychosocial and Visual Characteristics

Power of Contact lens (please circle) +0.75D +1.50 +2.50D

DATE QUESTIONNAIRE COMPLETED: _____/____/____
Month/Day/Year

PATIENT’S NAME: ______________________ ____________________________ ____________
First **Last** **Last 4 SSN**

We are interested in finding out about your current vision while wearing your contact lens provided at the last visit, and it’s effect on your vision, job, and daily function. We are interested in **your** opinions, ideas, and experiences. There are no right or wrong answers. All of the information you provide is confidential and will be published **only** in summary statistical form. You will not be identified in any way.

The information you give us will not affect your health care, or your vision care in any way.

In order to get accurate information about refractive surgeries and how they affect people's vision, we need information from **all** patients.

This questionnaire has 5 pages. If your copy does not have 5 pages, please contact the person administering the questionnaire.

PLEASE READ EACH QUESTION AND SELECT THE ANSWER THAT BEST REPRESENTS YOU.

1) These questions ask about your **current** use of corrective lenses for **DISTANCE VISION**. In answering these questions please think about your vision **while wearing the contact lens and using both eyes during the last week.** While you are **AWAKE**, do you currently wear glasses or contact lenses in **either** eye to improve your eyesight at **DISTANCE**? Please indicate what percentage of the time you wear ***contact lenses, glasses or neither***.

PERCENT OF TIME WEAR **GLASSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **CONTACT LENSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **NEITHER** GLASSES **NOR** CONTACT LENSES

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

TOTAL of above 3 questions for DISTANCE VISION: 100%

2) My *DISTANCE VISION* while wearing the contact lens, **using both eyes**, ***is excellent.***

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

3) These questions ask about your **current** use of corrective lenses for **NEAR VISION**. In answering these questions please think about your vision **while wearing the contact lens and using both eyes during the last week.** While you are **AWAKE**, do you currently wear glasses or contact lenses in **either** eye to improve your eyesight at **NEAR**? Please indicate what percentage of the time you wear ***contact lenses, glasses or neither***.

PERCENT OF TIME WEAR **GLASSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **CONTACT LENSES**

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

PERCENT OF TIME WEAR **NEITHER** GLASSES **NOR** CONTACT LENSES

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

TOTAL of above 3 questions for NEAR VISION: 100%

4) My NEAR VISION ***while wearing the contact lens***, *using both eyes* is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

5) What percentage of your daily tasks you are able to complete ***while wearing the contact lens?***

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

6) ***While wearing the contact lens****, using both eyes* which of the following items are you be able to see? (please circle)

G) Newspaper Headline
H) Dashboard
I) Computer screen
J) Watch
K) Cellular phone
L) Medicine bottle label

7) Is wearing your contact lens any inconvenience to you?

No inconvenience Extremely inconvenient

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

8) Would you consider this monovision trial successful?

1) Yes 2) No

8a) Rate the success of your monovision

Not successful Very Successful

0…….1…….2…….3…….4…….5…….6…….7…….8…….9…….10

9) People have different experiences with their vision. Some people have problems with **sharpness** or **clarity** where the edges seem fuzzy or indistinct. Please indicate whether you now—that is within the **last week while wearing your contact lens,** *using both eyes*—have problems with **sharpness** or **clarity** in any of the following situations.

On a scale of 1 to 10, where **1** stands for **"no problems"** and **10** stands for **"disabling problems,"** how much trouble do you have with **sharpness or clarity:**

CLARITY	**No Problems**	**Disabling Problems**
A. At night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
B. During work?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
C. From oncoming car headlights at night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
D. When watching television or using a computer monitor?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
E. When reading a brightly illuminated road sign at night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	

12) People have different experiences with their vision. Some people have problems with **halos, rings** or **starbursts** around objects or lights. Please indicate whether you now—that is within the **last week while wearing your contact lens,** *using both eyes*—have problems with **halos, rings** or **starbursts** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **"no halos"** and **10** stands for **"disabling halos,"** how much trouble do you have with **halos:**

HALOS	**No Halos**	**Disabling Halos**
A. At night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
B. During work?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
C. From oncoming car headlights at night? . .	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
D. When watching television or using a computer monitor?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	
E. When reading a brightly illuminated road sign at night?	1. . . . . 2. . . . . 3. . . . . 4. . . . . 5. . . . . 6. . . . . 7. . . . . 8. . . . . 9. 10	

13) People have different experiences with their vision. Some people have problems with **glare** or **light sensitivity**. Please indicate whether you now—that is within the **last week**—have problems with **glare** or **light sensitivity** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **"no glare"** and **10** stands for **"disabling glare,"** how much trouble do you have with **glare:**

GLARE	**No Glare**	**Disabling Glare**
A. At night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
B. During work?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
C. From oncoming car headlights at night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
D. When watching television or using a computer monitor?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
E. When reading a brightly illuminated road sign at night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	

14) People have different experiences with their vision. Some people have problems with **hazy** or **foggy vision**. Please indicate whether you now—that is within the **last week while wearing your contact lens,** *using both eyes*—have problems with **hazy** or **foggy vision** in any of the following situations.

On a scale of 1 to 10 where **1** stands for **"no haze"** and **10** stands for **"disabling haze,"** how much trouble do you have with **haze:**

HAZE	**No Haze**	**Disabling Haze**
A. At night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . 10	
B. During work?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
C. From oncoming car Headlights at night? . .	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
D. When watching television or using a computer monitor?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	
E. When reading a brightly illuminated road sign at night?	1. . . . 2. . . . 3. . . . 4. . . . 5. . . . 6. . . . 7. . . . 8. . . . 9. . . . 10	

15) My ability to judge distances **while wearing your contact lens** is excellent.

Strongly agree Strongly Disagree

0…….1…….2…….3…….4…….5…….6…….7…….8…….9….10.