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Differences in contrast sensitivity between pre- and post-operative LASIK patients

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Abstract

LASIK is currently the most common refractive surgery performed in the U.S. Traditionally the success and outcome of LASIK is assessed by using a high contrast Snellen chart. This provides limited information since our environment is composed of varying contrasts. Evaluating contrast sensitivity provides a more functional assessment of overall visual ability after LASIK. However, there is little information concerning this subject. This study further investigated the effect ofLASIK on contrast sensitivity. Preoperative and 5 and 10 week postoperative contrast sensitivity measurements were taken on 28 eyes of 14 subjects who underwent bilateral LASIK. The spatial frequencies of 1.5, 6.0, 12.0, and 30.0 cpd were tested. There was no statistically significant decrease in contrast sensitivity at the 1.5, 12.0, and 30.0 cpd between preoperative and the 5 week postoperative exam. There was a statistically significant decrease at the 6.0 cpd spatial frequency at 5 weeks post LASIK. By 10 weeks after LASIK, this decrease was no longer statistically significant. There was no statistically significant decrease in contrast sensitivity at the 1.5, 12.0, and 30.0 cpd from the preoperative through to the 10-week postoperative exam. Further research needs to be performed in order to determine the cause of any decrease in contrast sensitivity after LASIK surgery.

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DIFFERENCES IN CONTRAST SENSITIVITY BETWEEN PRE- AND POST-OPERATIVE LASIK PATIENTS

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ABSTRACT

LASIK is currently the most common refractive surgery performed in the U.S. Traditionally the success and outcome of LASIK is assessed by using a high contrast Snellen chart. This provides limited information since our environment is composed of varying contrasts. Evaluating contrast sensitivity provides a more functional assessment of overall visual ability after LASIK. However, there is little information concerning this subject. This study further investigated the effect of LASIK on contrast sensitivity. Preoperative and 5 and 10 week postoperative contrast sensitivity measurements were taken on 28 eyes of 14 subjects who underwent bilateral LASIK. The spatial frequencies of 1.5, 6.0, 12.0, and 30.0 cpd were tested. There was no statistically significant decrease in contrast sensitivity at the 1.5, 12.0, and 30.0 cpd between preoperative and the 5 week postoperative exam. There was a statistically significant decrease at the 6.0 cpd spatial frequency at 5 weeks post LASIK. By 10 weeks after LASIK, this decrease was no longer statistically significant. There was no statistically significant decrease in contrast sensitivity at the 1.5, 12.0, and 30.0 cpd from the preoperative through to the 10-week postoperative exam. Further research needs to be performed in order to determine the cause of any decrease in contrast sensitivity after LASIK surgery.

Introduction

Nearly half of the U.S. population has a refractive condition.[1] Myopia exists in about 25% of the population while about 20% of the population is hyperopic.[1,2] Astigmatism is also prevalent in about 30% of eyes with refractive conditions.[1] Traditional ways of correcting these refractive conditions have been through the use of corrective lenses or contact lenses. Beginning in the late 1970's a new method of vision correction was introduced with the advent of refractive surgery, specifically in the form of radial keratotomy (RK).[3] Photorefractive keratectomy (PRK) then followed in the 1980's, and in the 1990's laser assisted-in-situ-keratomileusis (LASIK) emerged as a choice for refractive surgery.[3,4] LASIK is now the most common refractive surgery performed today.

LASIK involves using a microkeratome to create a corneal flap, which is lifted back, and a 193-nm excimer laser is used to ablate the stromal bed of the cornea to create a refractive change. The flap is then repositioned back onto the cornea.[1,3,4,5,6,7] LASIK has been shown to be relatively safe and effective for the correction of myopia.[1,3,4,5,8,9] The traditional way of evaluating the success and outcome of LASIK has been measuring a person's visual acuity with a Snellen chart. This only evaluates a person's ability to resolve small details at high contrast. It does not assess a person's ability to see objects at different contrast levels, which is more analogous to everyday living conditions. The human environment is not solely a high contrast environment. Instead, we are faced with varying contrast and lighting conditions throughout our day, such as driving in a rainy environment at dusk or driving thru fog.

Evaluating a person's contrast sensitivity provides a more functional and useful assessment of a person's visual ability. It allows us to determine a person's ability to detect objects of varying spatial frequencies in varying contrast levels.[10,11,12,13] Contrast sensitivity is the ability to detect the presence of minimal luminance differences between objects or areas in space. It is equal to the reciprocal of contrast threshold.[5,14,15,16] Thus, performing contrast sensitivity testing to assess a person's visual ability after undergoing LASIK provides more useful and beneficial information than measuring Snellen visual acuity alone.

Past studies have used contrast sensitivity testing to evaluate the outcome of LASIK. Perez-Santonja et al. evaluated 14 eyes that underwent LASIK and found that 1 month after surgery contrast sensitivity was decreased significantly at the low (3 cpd) and intermediate (6 cpd) spatial frequencies. But by 3 months after surgery, the contrast sensitivity values returned to the preoperative values; there were no statistically significant differences between the 3-month postoperative and preoperative values. At 6 months postoperatively, higher contrast sensitivity values were found at the 3, 12, and 18 cpd but they were not statistically significant.[5] Holladay et al evaluated the contrast threshold of 14 eyes that underwent LASIK in 3 different lighting conditions (darkness, medium setting of the Brightness Acuity Tester (BAT), and high setting of the BAT). They found the contrast threshold in all 3 lighting conditions was decreased 1 day postoperatively. The contrast threshold values remained decreased 1 week, 1 month, and 6 months postoperatively, though the values improved over the time period.[17]

A growing number of people are choosing to undergo LASIK to manage their refractive condition yet there is very little information concerning the effect of LASIK on a person's contrast sensitivity. The two reported studies investigating the effect of LASIK on a person's contrast sensitivity involved small sample sizes and hence the results were preliminary. The purpose of this study was to further investigate the effect of LASIK on contrast sensitivity. We hypothesize that by 10 weeks postoperatively there would be no statistically significant difference between the preoperative and 10 week postoperative contrast sensitivity values.

Subjects

This study involved 28 eyes of 14 patients who underwent bilateral LASIK at the Laser Vision Correction Center in Beaverton, OR. The patients (8 female and 6 male) were students at Pacific University College of Optometry. Inclusion criteria for this study was, preoperatively, a best corrected visual acuity (BCVA) of 20/20, a refractive error of –1.00 to –10.00 diopters (D), 4.00 D or less of astigmatism, no history of ocular pathology, no systemic collagen disorder, and realistic expectations. Subjects who wore RGP or soft contact lenses were required to discontinue the use of the lenses prior to the surgery according to the following criteria: for RGP's, 1 month for every decade of wear; for soft contact lenses, 1 week for every decade of wear.

The mean age of the patients was 25.71 years ± 1.73 (SD) (range 23 to 30 years). The mean spherical refractive error, preoperatively, was –4.88 ± 2.12 D (range –0.50 to –9.00 D) and mean astigmatism was –0.83 ± 0.91 D (range –0.0 to –3.75 D). The mean spherical equivalent refractive error was –5.29 ± 1.98 D (range –1.38 to –9.13 D).

Methods

Pacific University College of Optometry third and fourth year interns in conjunction with attending doctors conducted the preoperative and postoperative examinations. The preoperative examination included case history, contact lens history, pupil evaluation, extraocular muscle evaluation, confrontation visual fields, intraocular pressure measurement using a Tonopen, visual acuity, manifest and cycloplegic refractions, keratometry, corneal topography (Zeiss Humphrey Instruments), biomicroscopy, high plus funduscopy, binocular indirect ophthalmoscopy, and corneal thickness measurement (Chiron Intraoptics System Corneal Gauge III pachymeter). The 1 day, 1 week, 5 week, and 10 week postoperative examination included case history, visual acuity, manifest refraction, corneal topography, and biomicroscopy. The attending optometric physicians rechecked all preoperative and postoperative refractions. Contrast sensitivity measurements preoperatively and postoperatively were taken with the B-VAT II-SG (Mentor) and were performed by the researchers.

Prior to the LASIK surgery, pupil measurements were again taken with the Colvard Pupilometer. All LASIK procedures were performed with the VISX Star S2 laser (target fluence of 160 mJ/cm2) and the Moria microkeratome. The microkeratome created superior flap diameters of 8.5-9.0 mm and an average flap thickness of 140 microns (86.0-193 microns). A single zone approach with a repetition rate of 10 Hz was used with either a 6.0 or 6.5 mm ablation zone depending on the patients' refractive profile. Protective eye goggles were worn upon completion of surgery through to the postoperative exam the following morning and at bedtime for 1 week thereafter. An antibiotic-steroid combination eye drop (tobramycin 0.3% and dexamethasone 0.1%, Tobradex® 2.5 mL) was instilled four times each day for 1 week. Lubricating eye drops (Refresh Tears) were also instilled a minimum of four times each day for 1 month.

The B-VAT II-SG was used for contrast sensitivity testing at the preoperative and at the 5 week and 10 week postoperative exams. A trial run of contrast sensitivity testing was conducted prior to the preoperative exam to negate any learning effect that might have occurred. At each session, the spatial frequencies of 1.5, 6.0, 12.0, and 30.0 cycles/degree (cpd) were tested. The instrument was calibrated and set at 14 feet. The testing was performed in normal room illumination (60 foot candles). The contrast sensitivity measurements were conducted with the patient's best spectacle-corrected visual acuity through the use of trial lenses and a trial frame. Patients were asked to identify the direction of the sine-wave gratings for each of the tested spatial frequencies. A staircase method was used to determine the contrast threshold level. The staircase method, which determines ascending and descending contrast threshold values, was used to determine the contrast threshold values.

These ascending and descending threshold values were used to calculate the contrast sensitivity mean at each of the tested spatial frequencies. The repeated measures analysis of variance (ANOVA) and the post-hoc Scheffe test were used for statistical analysis. Statistical differences were considered significant when the P-value was less than 0.05.

Results

Preoperative and postoperative contrast sensitivity was measured on 28 eyes of 14 patients. Prior to LASIK surgery the mean spherical equivalent refractive error was –5.29 ± 1.98 D (range –1.38 to –9.13 D). Postoperatively the mean spherical equivalent error at 5 weeks was +0.72D ± 0.63 (range +1.75 to –1.00) and +0.31D ± 0.56 at 10 weeks (range +1.50 to –1.00). An ANOVA test was performed which showed a statistically significant reduction in refractive error from preoperative values to 5 weeks post LASIK ($p<0.0001$). There was no significant postoperative change in refractive error from 5 to 10 weeks (table 1). All 28 eyes were evaluated as one group and there was no classification into low, medium and high myopes or astigmats.

Figure 1 shows the statistically significant change in mean refractive error from moderate myopia preoperatively to low hyperopia following LASIK. This trend represents a mild overcorrection in the refractive error. Although there was no statistically significant change in mean refractive error between the 5-week and 10 week postoperative visits, there appeared to be a slight trend toward regression during that time period. Mean spherical equivalent refractive error changed from +0.72 at 5 weeks to +0.32 at 10 weeks post-LASIK.

Table 1. Pre and Post-LASIK Means for Refractive Error (N = 28 eyes)

	Count	Mean	Std. Dev.	Std. Err.
Pre-op Rx	28	-5.29	1.98	0.37
5 Week Post	28	+0.72	0.63	0.12
10 Week Post	28	+0.32	0.56	0.11

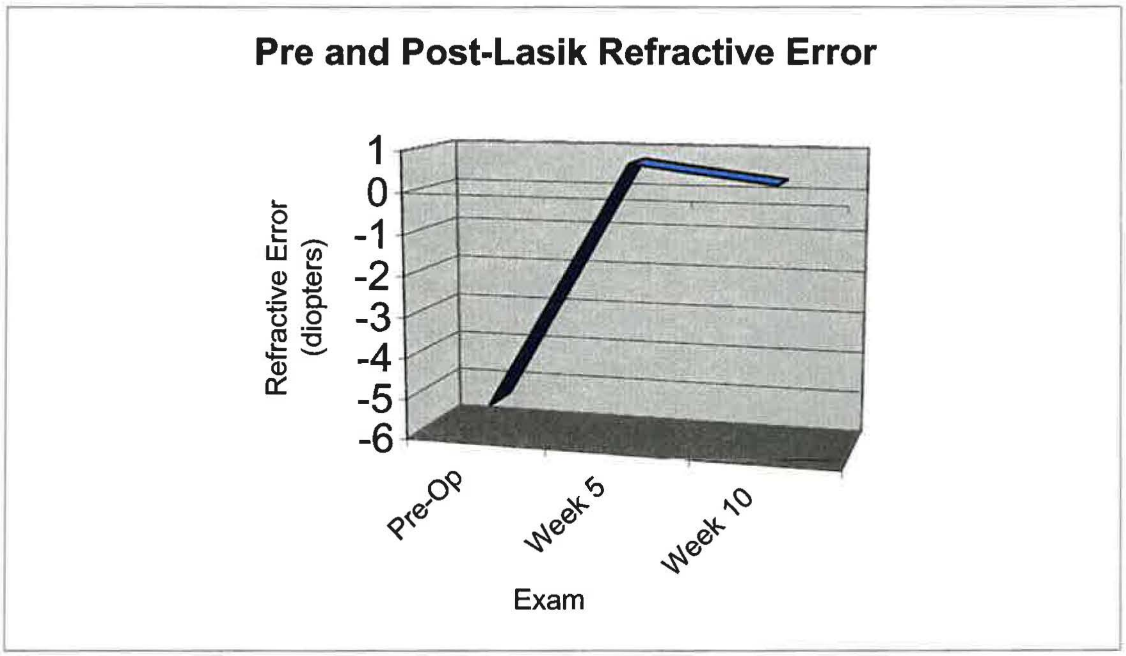

Figure 1. Pre and Post-LASIK Refractive Error, (N = 28 eyes)

The mean contrast sensitivity values at each cycle per degree (cpd) tested preoperatively and postoperatively for all 28 eyes are shown in table 2. There was no statistically significant change in contrast sensitivity from preoperative measurements to 10-week postoperative measurements. For the 28 eyes, the p value was greater than 0.05 when comparing preoperative through to 10 week contrast sensitivity at 1.5, 12.0, and 30.0 cpd spatial frequencies tested (p = 0.9699, p = 0.1735, p = 0.3587 respectively). There was, however, a change at the 6 cpd spatial frequency when comparing preoperative contrast sensitivity values to those through the10 week measuring period (p=0.0109). There was no subject with outlying data to explain the decrease at this spatial frequency.

Table 2. Pre and Post-LASIK Contrast Sensitivity values, (N = 28 eyes)

Spatial Frequency (cpd)	Exam	Mean Contrast Sensitivity ± SD	Range of Contrast Sensitivity
1.5	Pre-Op	194.393 ± 141.303	625.00 to 63.00
	5 Week	189.393 ± 102.288	395.00 to 63.00
	10 Week	185.946 ± 127.548	395.00 to 63.00
6.0	Pre-Op	436.304 ± 247.103	815.00 to 81.50
	5 Week	267.964 ± 185.724	700.00 to 81.50
	10 Week	372.679 ± 203.108	700.00 to 100.00
12.0	Pre-Op	164.946 ± 119.745	515.00 to 40.00
	5 Week	115.714 ± 69.625	280.00 to 20.50
	10 Week	141.732 ± 108.080	395.00 to 32.50
30.0	Pre-Op	10.179 ± 15.216	70.00 to 1.00
	5 Week	6.537 ± 9.493	44.00 to 1.00
	10 Week	10.705 ± 15.128	62.50 to 1.15

Upon closer evaluation the decrease in contrast sensitivity was found to be only at 5 weeks after LASIK (p=0.0161). By 10 weeks post LASIK, contrast sensitivity levels at 6 cpd had returned to preoperative levels. In this comparison, contrast sensitivity was significantly lower at 5 weeks than preoperative and 10-week contrast sensitivity levels. There was no statistically significant decrease in contrast sensitivity values between preoperative and 10 weeks (p=0.5397) at the 6 cpd spatial frequency.

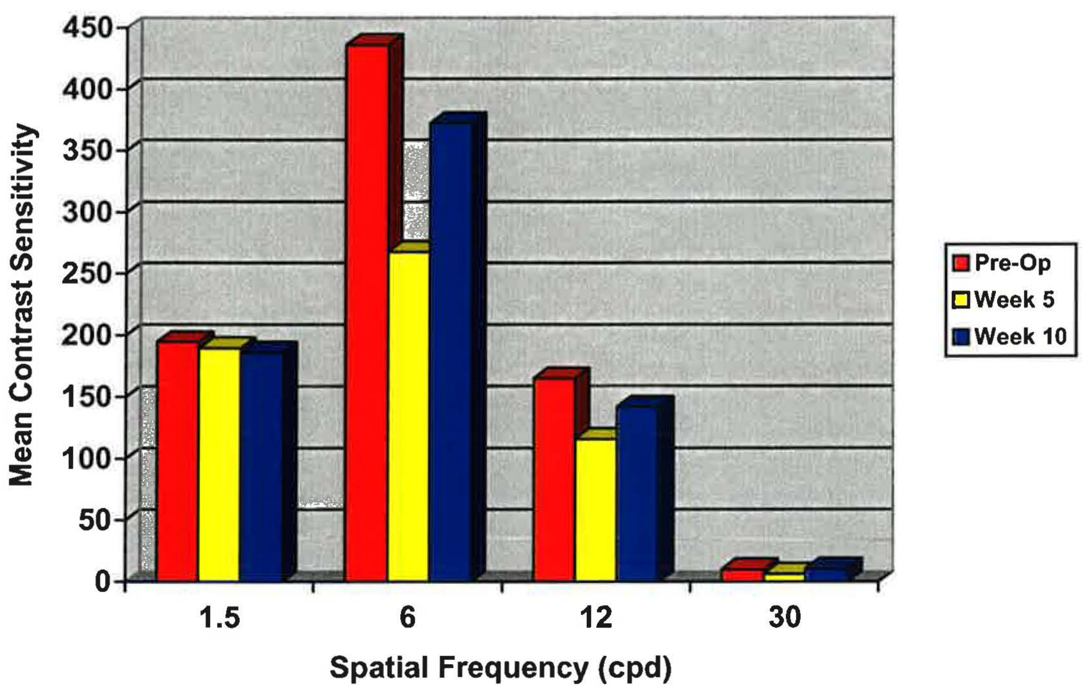

Figure 2. Pre and Post-LASIK Contrast Sensitivity, (N = 28 eyes)

Figure 2 shows that by 5 weeks post LASIK, contrast sensitivity returned to preoperative levels at the high and low spatial frequencies of 1.5, 12.0, and 30.0 cpd. The contrast sensitivity at the mid-range spatial frequency of 6 cpd returned to preoperative levels by 10 weeks after LASIK. Therefore, at all spatial frequencies tested, there was no statistically significant decrease in contrast sensitivity between preoperative values and 10 weeks post LASIK. Although there was no statistically significant change in contrast sensitivity at the 30 cpd spatial frequency, a slight overall increase in contrast sensitivity was observed at 10 weeks post LASIK.

Discussion

In clinical settings visual performance is evaluated before and after refractive surgery through Snellen visual acuity, a black on white high contrast measurement of vision. This test provides limited information of vision across the broad range of low, medium, and high contrast, which exists in every day life. In the past, success and predictability of refractive surgery including LASIK have been based on these Snellen acuity measurements. A postoperative testing protocol including low and medium and high contrast sensitivity measurements would allow for a more functional and useful assessment of overall visual ability.[5,12,13,14,18] In our environment there exist changes in brightness across space. The human eye resolves targets differently under varying contrast levels.[5,10-17] Contrast sensitivity testing would measure the resolving power of the eye over a much broader spectrum than Snellen acuity alone.[5]

Our study evaluated contrast sensitivity on 28 eyes of 14 subjects that showed no significant change at all spatial frequencies of 1.5, 6.0, 12.0, and 30.0 cpd by 10 weeks postoperatively. There was, however, a small yet statistically significant decrease at 6 cpd at five weeks. This may explain many patients' complaints of decreased vision shortly after LASIK even though through Snellen acuity testing they measure 20/ 20 vision. Since there is no decrease in contrast sensitivity at the high spatial frequencies such as 30 cpd, which corresponds to 20/20 Snellen acuity, patients are able to resolve the letters on this high contrast test. These same patients may have trouble shortly after surgery in real world environments where medium to low contrast exits, such as driving at dusk. This may correspond to the decrease in contrast sensitivity at the 6 cpd (medium) spatial frequency at five weeks after LASIK Patients symptoms should improve gradually since at ten weeks, our study showed no statistically significant change at the 6 cpd spatial frequency, contrast sensitivity had returned to preoperative values. The changes found at this mid-range spatial frequency could be caused by some of the complications that can arise from refractive surgery. Complications that may arise include microstriae, dryness, irregular astigmatism, haloes and glare, higher order optical aberrations, epithelial cells and debris at the interface, and corneal haze which is more of a problem in PRK than LASIK.[1,3,4,6,7,19,20]

Faint postoperative microstriae were noted in many of the patients, which may be a cause for decreased contrast sensitivity. If microsurface irregularities are induced by the LASIK procedure, incoming light through the cornea is scattered and does not focus to a fine point on the retina.[4] Best corrected vision through the use of lenses may help to diminish but not eliminate the effects of microstriae. Any residual refractive error was corrected for with the use of lenses and all patients had best corrected vision of 20/20 or better of Snellen visual acuity accept for one subject with reduced best corrected vision to 20/25 in one eye. Haloes were unlikely to be the cause of any change in contrast sensitivity since all patients were measured with the colvard pupillometer prior to LASIK surgery and the treatment zones were appropriate for pupil size. Higher order optical aberrations, such as coma or spherical aberration, may play a part in the decrease in contrast sensitivity, although no testing was performed during this study to validate this theory. No subjects in this study developed postoperative corneal haze, making haze an unlikely culprit for the observed decrease the contrast sensitivity values.

Conclusion

For many years, eye care professionals have sought out a way to correct refractive errors to allow freedom from reliance on spectacle correction or contact lenses. Myopia, hyperopia, and astigmatism exist in a large portion of the population and many different procedures have been used to correct these refractive errors in order to eliminate dependence on glasses or contacts.[1] Some of the more common refractive surgeries include RK, IOL implants, PRK, and LASIK. LASIK is the most common refractive surgery performed today due to its greater predictability with moderate to high myopia, reduced complications, and quick recovery period.[1,4] Still, greater predictability does not imply perfection with these surgical techniques. Further testing following surgery must be done to determine complete postoperative visual function.

Many studies have evaluated contrast sensitivity following PRK and RK with fewer studies on LASIK due to its more recent advent on the refractive surgery scene. Most studies on RK and PRK have shown a decrease at certain contrast levels during the period of corneal healing with a final outcome of visual function returning to preoperative levels.[12,14] Ghaith et al determined a decrease in contrast sensitivity after RK and PRK up to the sixth postoperative month. Beyond six months no statistically significant change in contrast sensitivity was observed.[14] Conversely, Verdon et al showed a reduction in low and high contrast visual acuity one year after PRK using different contrast testing methods.[18]

Previous contrast sensitivity studies performed on LASIK patients have similarly been in mixed agreement. The study by Perez-Santonja et al showed a decrease in medium (6 cpd) and low (3 cpd) spatial frequencies at one month, but returned to preoperative values by three months after surgery.[5] Another study by Wang et al concluded that contrast sensitivity returned to preoperative levels 3 months after LASIK.[8] Whereas, Holladay et al showed that low contrast sensitivity when tested in darkness had not returned to preoperative levels six months after LASIK surgery. Their study measured contrast sensitivity at varying light levels and determined that the aspheric change in the cornea was the predominant factor limiting visual performance, especially when lighting conditions where low and pupil size increased.[17] Our preliminary study measured contrast sensitivity at normal room illumination and showed that although there was a decrease in contrast sensitivity at the medium spatial frequency (6cpd) at 5 weeks, by 10 weeks contrast sensitivity had returned to preoperative levels at all spatial frequencies. While these studies are invaluable, further testing with a larger sample size is necessary.

Future research should attempt to determine the cause of this temporary decrease in contrast sensitivity at the intermediate spatial frequencies. This may show that microstriae, irregular astigmatism, epithelial cells and debris at the flap interface, higher order optical aberrations, and/or dryness may contribute to a decrease in contrast sensitivity at certain spatial frequencies. Additionally, ongoing research on contrast sensitivity at varying light levels may allow greater understanding of any optical aberrations that are induced by creating an oblate cornea after LASIK, and to what degree functional vision is affected due to normal pupil variance under different lighting conditions. Although LASIK surgery provides the desired freedom from glasses or contact lenses, further research should be performed to evaluate its true impact on overall functional visual performance.

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Biography Page

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