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Night vision of the post-LASIK myope

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Abstract

Purpose: Poor night vision has been reported as one of the side-effects of LASIK, however, this area has not been widely studied. This study therefore set out to assess and quantify the visual status of the post-LASIK patient in dim illumination as an indication of visual performance at night. This was achieved by assessing the night vision threshold, glare vision threshold and glare recovery time.

Setting: The study was carried out in Durban, Kwazulu-Natal in South Africa.

Method: This study used the Night Sight Meter for assessment of the night vision thresholds, glare vision thresholds and glare recovery times of individuals who had had LASIK at least one year before commencement of the study. The inclusion criteria were post-surgical interval following LASIK of at least one year and willingness to participate in the study. The exclusion criteria included previous ocular surgery other than LASIK, current ocular disease and any systemic illnesses. One hundred subjects were selected from participating ophthalmologists' records, using convenience sampling, at different post-operative periods that ranged from 12 to 57 months. Other refractive findings taken included post-LASIK visual acuity measured using the Snellen Visual Acuity chart and post-LASIK refractive error, measured with the standard subjective refraction tests which included duochrome, Jackson crossed-cylinder and Humphrey's Immediate Contrast test, which are used for comparison in this study.

Results: Post-operatively, the majority of the eyes (89.2%) were classified as having 'poor' night vision thresholds. A similar trend was observed in the case of the glare vision thresholds as 84.7% of the eyes fell into the classification of below average. The degree of pre-operative myopia appears to have an effect on the post-LASIK night vision and glare thresholds. Only glare recovery time was not affected as 51.2% of the subjects displayed good recovery times.

Conclusion: This study suggests that the post-LASIK myope has difficulty with night vision due to poor night vision and glare vision thresholds which are linked to the higher aberrations and intraocular scatter resulting from LASIK. As macular integrity is not affected in the LASIK patient, the glare recovery time appears to be within normal limits.

Introduction

Laser assisted in-situ keratomileusis (LASIK) is surgery aimed at correcting refractive error and thus removing the need for spectacles or contact lenses. This technique has revolutionized the field of refractive error correction and has been reported to have superseded many other forms of refractive surgery such as radial keratotomy, and photorefractive keratectomy, in accuracy and stability of the refractive error[1].

Previous studies[2-5] reported good outcomes and minimal reduction in visual performance following the surgery. Questions, however, arise regarding the efficacy and safety of LASIK and its impact on visual status in the long-term[6-8]. One side-effect of LASIK that has been reported[9], is difficulty driving at night due to reduced vision at night.

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Human beings are primarily diurnal. However, the lifestyles of human-beings require that they be able to function adequately both during the day, as well as, at night. The main activity that they are required to perform adequately and safely at night is often driving. Driving is a visually demanding task since vision provides most of the information to a driver, with only a minor contribution from the hearing sense[10]. Refractive surgery has been found to result in a significant decrease in visual quality especially under mesopic and scotopic conditions and thus, is expected to have an impact on the ability of the patient to drive at night[11]. The Civil Aviation Authority in the United Kingdom, discourages pilots from undergoing LASIK because of reported reduction in night vision[12]. At the time of this study, no other studies were found that attempted to quantify night vision in the post-LASIK patient, other than a study by El Danasoury[13] which compared night glare to the ablation profile.This study, therefore, attempted to assess the night vision performance in the post-LASIK patient.

Methodology

Study design and sampling

A retrospective cross-sectional study design was employed. The study population also made up the study sample due to the limited number of subjects that were accessible. Subjects were obtained after consultation with three ophthalmologists who had been performing LASIK using the same excimer laser and microkeratome, at the same hospital. All myopic subjects who had previously undergone LASIK a year or longer ago, and who were willing to participate in the study after the purpose and nature of the study was explained to them, were included. Exclusion criteria included previous ocular surgery other than LASIK, current ocular disease and any systemic illnesses. Thus, the sample consisted of 100 subjects but 197 eyes, as three of these patients had LASIK performed on one eye only. Their ages ranged from 23 to 66 with a mean of 41.17 ± 5.38 years. Approximately 56% were male and 44% female. Analysis was done monocularly as surgery was done on each eye independently of the other. The post-LASIK period ranged from 12 to 58 months (that is, between one and six years). All pre-operative data was obtained from the record cards of these subjects. Based on the classification of myopia by Obstfeld[14] the pre-operative refractive errors of the subjects included 19% of low myopes, 57.9% of moderate myopes and 23.1% high/very high myopes. Hence subjects have been classified as either being low, moderate, high or very high myopes based on their pre-operative refractive error.

Materials and procedure

Night vision performance was assessed using the Night Sight Meter (ISO Optical), which is an instrument (see Plate 1) designed to simulate night driving conditions.

The instrument measures an individual's night vision threshold, glare vision threshold and glare recovery time. The Night Sight Meter was placed on a table approximately 70 cm wide in a room that had no windows from which light may have caused reflection inside the test unit. The test targets consisted of 15 Landolt C's, in four orientations, which passed through a diamond shape opening in the upper left corner of the unit at a rate of 45 Landolt C's per minute. Since there is an apparent movement of objects when driving, the continuous movement of the targets is important in simulating these conditions. Illumination of the targets was provided by a 6 Watt 115 Volt lamp and the amount of light on the targets was controlled by a rheostat. Glare lights was provided by two 6 Watt 115 Volt lamps located at the upper right rear of the test unit. The tester also consisted of a light emitting diode digital display timer used for measuring the glare recovery time, linked to a touch time stop switch, which the subject was made aware of at the beginning of this test.

Plate 1: Night Sight Meter

The assessment of night vision was done monocularly. The test was performed unaided which was currently the habitual state of the subjects. The test was done in the dark. The subject was allowed approximately three minutes to adapt by sitting in the dark room, before the testing started. There were three parts to this test. The subject was instructed to keep his or her face pressed against the eye-shade until all three parts of the testing were completed.

Test One – Night vision threshold

This test assessed the subject's ability to see under conditions of low illumination. The level of illumination was decreased from 100 units, which is the maximum illumination, by means of the rheostat and the subject was asked to call out the orientation of the openings in the Landolt C letters. The light was turned down by one unit for each Landolt C identified correctly until the subject started missing the Landolt C's or gave up.

The night vision threshold scores (the unit amount of illumination between 0 and 100) were categorized based on the values as specified in the manual of the tester (ISO Optical) (Table 1).

Table 1. Categorization of Night Sight Meter readings

	Night Vision Threshold (units of illumination)	**Glare Vision Threshold (units of illumination)**	**Glare Recovery Time (secs)**
A – GOOD	0 – 15	0 – 30	0 – 1.5 s
B – ABOVE AVERAGE	16 – 20	31 – 40	1.6 – 2.5s
C – AVERAGE	21 – 25	41 – 55	2.6 – 4s
D - BELOW AVERAGE	26 – 35	56 – 76	4.1 – 6s
E – POOR	> 35	> 77	> 6s

Test Two – Glare vision threshold

Glare vision threshold, as measured by the night sight meter, refers to the subject's night vision threshold in the presence of a glare source. The glare source was switched on and the subject once again called out the orientation of the stimuli (Landolt C's) whilst the knob was turned down one unit at a time until the subject had difficulty identifying the orientation. The minimum amount of lighting, with the glare source on, required to detect and correctly identify the orientation of the target was recorded as the glare vision threshold score.

The glare vision threshold scores were categorized based on the values as specified by the manufacturers of the tester (ISO Optical) (Table 1).

Test Three – Glare recovery time

For glare recovery time, the rheostat was set to the average night vision score which had been determined in test one, and at the onset it was ensured that the subject could see the target. The subject was reminded about the touch timer stop switch which he or she was shown prior to starting test one. The glare source was then switched on for 10 seconds. Once the glare source was switched off, the timer started running automatically. The subject was instructed to stop the timer only once the glare source goes off and he or she can properly see the orientation of the Landolt C stimuli. At that point, they were asked to call out the orientation of the C's. The glare recovery time, in seconds, was then read off the digital display timer.
The glare recovery time scores were categorized based on the values as specified by the manufacturers of the tester (ISO Optical) (Table 1).

For each test, three readings were obtained. The average score was recorded and the procedure was repeated on the other eye. Each test took approximately two minutes to perform.

Results and Discussion

Night vision thresholds

Night vision threshold in this study refers to the minimum amount of illumination that the subject required to detect the test object under scotopic conditions. Thus, the higher the night vision threshold, the poorer is the subject's night vision.

Table 2. Categorization of night vision thresholds for the different degrees of pre-operative refractive errors in the different post-operative intervals

	POST-OPERATIVE INTERVAL										
CATEGORY	***12 –23 months***			***24 - 35 months***			***36 – 48 months***			***> 48 months***	
	Low (% of eyes) (n=16)	Mod (% of eyes) (n= 44)	High (% of eyes) (n= 11)	Low (% of eyes) (n= 10)	Mod (% of eyes) (n= 40)	High (% of eyes) (n=12)	Low (% of eyes) (n=8)	Mod (% of eyes) (n=26)	High (% of eyes) (n=19)	Low (% of eyes) (n=2)	High (% of eyes) (n=2)
GOOD	0	0	0	0	0	0	0	0	0	0	0
ABOVE AVG	0	0	0	0	0	0	0	0	0	0	0
AVERAGE	0	0	0	0	0	0	0	0	0	0	0
BELOW AVG	12.5	6.8	0	30	13.6	0	37.5	11.5	5.3	0	0
POOR	87.5	93.2	100	70	86.4	100	62.5	88.5	94.7	100	100

All subjects had high night vision thresholds that fell in the classification of below average, with the majority of eyes (89.2%) being classified as having poor night vision thresholds. This implies poor ability to see under low illumination. When a comparison of night vision thresholds for the different degrees of myopia was made, irrespective of duration following LASIK, no significant differences were found (high *vs* low $p = 0.464$; high *vs* mod $p = 0.081$; low *vs* mod $p = 0.257$). However, all the high myopes (100%) in the duration 12 to 35 months, and the majority (94.7%) of high myopes in the duration 36-48 months, had night vision thresholds that were significantly higher than those of the moderate and low myopes at these durations (Table 2). For the post-operative interval 24-35 months, the high myopes showed significantly higher mean night vision thresholds compared to the low myopes ($p= 0.004$) and the moderate myopes ($p=0.018$). Also, the high myopes had significantly higher night vision thresholds than the low myopes at the 36 - 48 months post-operative interval ($p=0.017$). This trend is further illustrated in Figure 1.

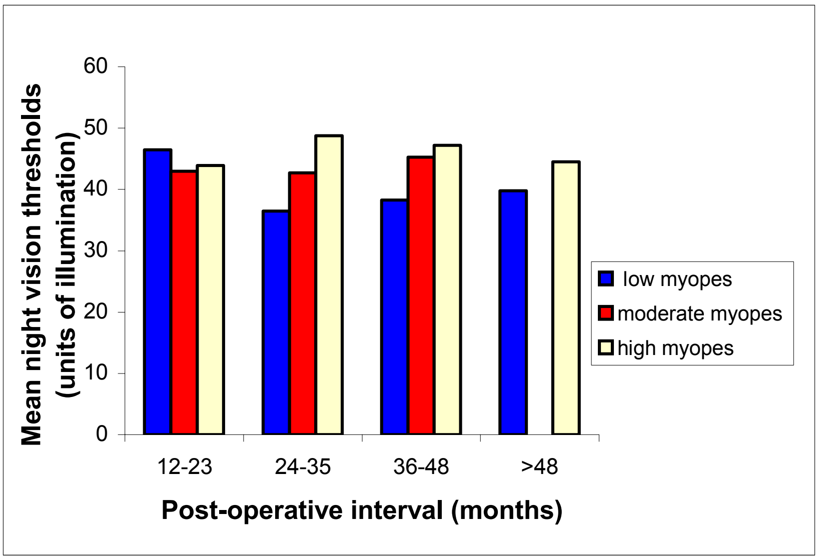

Figure 1.Mean night vision thresholds according to degree of pre-operative refractive error and the post-operative interval (months)

It is expected that the high myopes would have poorer night vision thresholds due to the higher amount of correction required resulting in thinner post-operative corneas, which are subject to more irregularities and consequently can have poorer contrast sensitivities. The only exception occurred in the post-operative interval 12-23 months, where the low myopes were found to have higher night vision thresholds, which were also significantly higher than that of the high myopes. This finding could be due to incomplete healing and stabilization in those eyes that had LASIK recently.

There was no significant association between the night vision threshold and the post-operative period (Pearson's correlation coefficient $r = 0.002$; $p = 0.977$). However, a significant Pearson's correlation was found between the post-operative spherical equivalent and the night vision threshold ($r = -0.194$; $p = 0.007$), and post-operative visual acuity ($r = -0.261$; $p = 0.000$) and night vision threshold. Thus, eyes with higher post-operative spherical equivalent residual errors, and consequently poorer visual acuity had poorer night vision thresholds. This is expected since as the resolution capability of the eye decreases, so will the visual acuity. Therefore, more contrast and thus lighting will be required to discern an object under dim illumination.

These findings are consistent with those of previous studies[5, 15-19] which, have shown that most changes following refractive surgery occur in low contrast visual acuity and also in high contrast visual acuity measured under low illumination. This reduction in visual acuity and contrast sensitivity under low illumination has been attributed to a decrease in contrast modulation, image degradation, increase in flare, increase in aberrations, ghosting and loss of contrast post-operatively[18-20]. The resultant effect is that functional vision worsens under diminished target contrast and increased pupil size[15, 20-22] as is the case when driving at night. Furthermore, the reported decrease in low contrast vision due to intraocular scattering of light and aberrations, reduces vision further when the pupils are dilated as in reduced illumination[16]. Spherical aberration in the centrally flattened cornea has been identified as the major cause of glare and haloes and debilitating night vision[13, 17, 23]. Fifth order aberrations (secondary coma), in particular, have been considered to be responsible for the debilitating vision at night[17]. Furthermore, at least a 1 D shift in the myopic direction, due to changes in accommodation in complete darkness, has been well documented[10, 16]. This increase in myopia will therefore further decrease the resolution capability of the post-LASIK eye under dim illumination. The implication of this, therefore, is that the patients with even a –0.50 D residual correction may require spectacles when driving at night, in areas where there may be are no lights or there is poor lighting. This is significant on freeways often where there may be poor lighting and drivers have to rely on their car headlights only. This also highlights the debate of accepting 6/12 VA as being adequate following LASIK. This visual acuity of 6/12, which has been measured under photopic conditions, may be further reduced under scotopic conditions consequently resulting in poor night vision. Post-operatively, patients therefore, may not satisfy the requirements to drive at night.

In Germany, a study reported that seven out of ten patients were found unfit to drive at night according to German law, due to glare following LASIK[19]. Kriegerowski (cited by Jory, 1996)[24] reported that 75% of his uncomplicated Photo Refractive Keratotomy (PRK) cases, had failed the Federal German night-time visual driving standards due to a loss of contrast sensitivity. Sekundo *et al*[5] also reported that 75% of patients, at six years following LASIK, complained of glare and haloes at night. Currently, in South Africa, tests performed to determine if the patient has adequate vision for driving, are done only under photopic conditions. This form of assessment should be reviewed and the patient's ability to see adequately to drive safely under scotopic conditions, should also be included in the driver's vision test. Fan-Paul *et al*[20] predicted an increase in the number of patients complaining of scotopic and mesopic vision disturbances following refractive surgery and as more people undergo surgery this issue could become a major public health problem.

Glare vision threshold

Glare vision threshold, as measured by the night sight meter in the present study, referred to the minimum amount of illumination that a subject requires to detect a test object under scotopic conditions, but in the presence of glare. As in the case of night vision thresholds, the higher the glare vision threshold, the poorer is the subject's night vision in the presence of a glare source. In this study the glare vision threshold for the majority of eyes (84.7%), irrespective of degree of myopia, or post-operative period, fell into the classification of below average (Table 3).

Table 3. Categorization of glare vision threshold for the different degrees of pre-operative refractive errors in the different post-operative intervals

	Post-Operative Interval										
Category	***12 –23 months***			***24 – 35 months***			***36 – 48 months***			***> 48 months***	
	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	High (% of eyes)
Good	0	0	0	0	0	0	0	0	0	0	0
Above Avg	0	0	0	0	0	0	0	0	0	0	0
Average	25	13.6	9.1	40	13.6	8.3	0	15.4	21.1	0	0
Below Avg	37.5	63.7	63.6	50	63.7	58.4	87.5	61.5	42.1	100	50
Poor	37.5	22.7	27.3	10	22.7	33.3	12.5	23.1	36.8	0	50

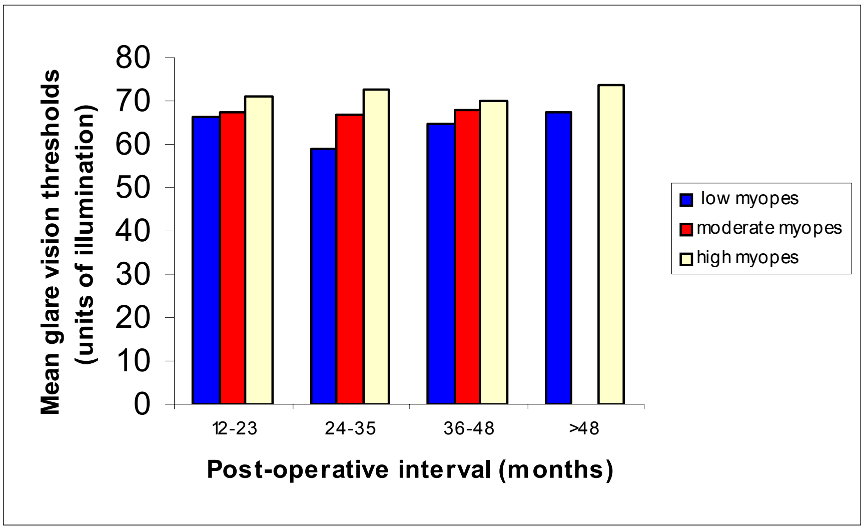

Figure 2. Mean glare vision thresholds according to degree of pre-operative refractive error and the post-operative interval (months)

In the present study, it was also found that the greater the degree of pre-operative myopia, the higher the glare vision threshold, although the differences were not always significant (Figure 2).

It was only at the duration 24-35 months that the glare vision threshold of the high myopes was significantly greater than that of the low and moderate myopes. This indicated that the high myopes had comparatively poorer night vision in the presence of a glare source than the moderate and low myopes. Similar findings have been reported from other studies, which expect an increase in haloes and glare with higher myopia because of a greater transition zone between the lasered and unlasered corneal tissue in these eyes, leading to the formation of central islands[12, 21, 25, 26]. Furthermore, following refractive surgery there can be an increase in spherical and higher order aberrations (coma, triangular astigmatism) as a result of the change in the prolate shape of cornea to an oblate shape. This change in shape is expected to be greater in high myopes due to the deeper ablation depths, which consequently leads to a greater degradation of the optical quality of the image[18]. Thus, the optical quality of the high myopes has been found to be reduced compared to the low and moderate myopes due to a greater amount of aberrations and intraocular scatter[16, 18, 27-29].

No significant correlation was found between glare vision threshold and the post-operative spherical equivalent, however, a significant correlation was found between glare vision threshold and the post-operative unaided visual acuity ($r = -0.258$; $p = 0.000$). This meant that as post-operative unaided VA improved, the sensitivity to glare decreased. Glare testing has been described by Chisholm[21] as an indirect measure of intraocular scatter. Intraocular scatter is caused by microfolds, interface particles and scars which will scatter light across the retina and thus lead to a decrease in contrast available for distinct usable vision. This would then result in difficulties with night vision especially in the presence of a glare source[6, 16, 21, 30]. It was found that the night vision thresholds and the glare vision thresholds were closely related as significant correlations were recorded between these two aspects ($p = 0.000$). Such a relationship is expected as reduced night vision will decrease even further in the presence of a glare source.

Glare recovery time

Glare recovery time, in the present study, refers to the minimum time required by the subject to adjust to low light illumination after a glare source has been extinguished. Therefore, the faster the recovery of good vision, the shorter the recovery time. Good to average glare recovery times (≤ 4 seconds) as indicated in the operational manual was recorded. Many (51.2%) of the subjects displayed good recovery times (Table 4) ranging between 0.45 and 1.50 seconds.

Table 4. Categorization of glare recovery times for the different degrees of pre-operative refractive errors in the different post-operative intervals

	Post-Operative Interval										
Category	***12 –23 months***			***24 – 35 months***			***36 – 48 months***			***> 48 months***	
	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	Mod (% of eyes)	High (% of eyes)	Low (% of eyes)	High (% of eyes)
Good	93.8	52.3	45.5	30	52.3	41.7	25	46.2	47.4	100	0
Above Avg	6.2	27.2	27.2	10	20.4	8.3	37.5	23	26.3	0	0
Average	0	16	9.1	10	15.9	16.7	25	11.6	26.3	0	0
Below Avg	0	0	0	40	6.9	16.6	0	19.2	0	0	0
Poor	0	4.5	18.2	10	4.5	16.7	12.5	0	0	0	100

There was no consistent trend with regards to the degree of myopia, or post-operative duration, and the glare recovery time, illustrated in Figure 3.

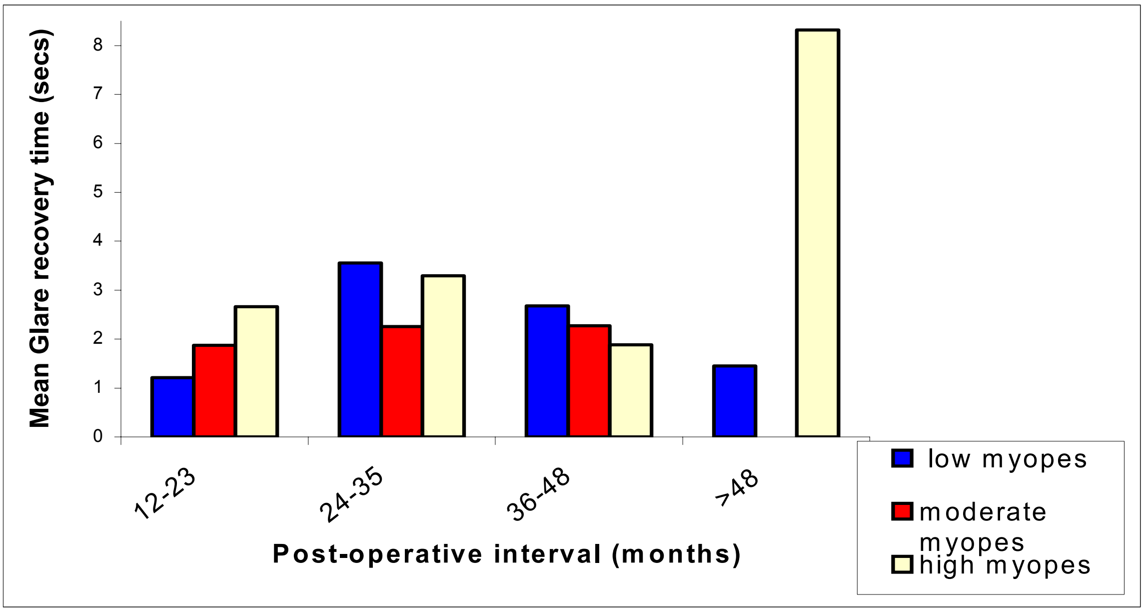

Figure 3 Mean glare recovery times according to degree of pre-operative refractive error and the post-operative interval (months)

No correlation was found between the glare recovery time and the post-operative spherical equivalent, but a significant correlation ($r = -0.233$; $p = 0.001$) was found with post-operative unaided VA. This means that the poorer VA, the longer the time taken to recover from glare.

It has been reported that glare recovery time is dependant more on macular integrity rather than corneal regularity and thus, is not affected significantly by refractive surgery[31].

Conclusion

Night vision and glare vision thresholds of myopes appear to be reduced following LASIK with the high myopes appearing to be affected more than the low and moderate myopes. The higher the post-operative refractive error, the poorer the post-operative visual acuity and thus this has a greater effect on the night vision and glare vision thresholds. Glare recovery time does not appear to be affected by LASIK. It is recommended that a future study should assess night vision pre and post-LASIK, which would allow for definitive conclusions as to whether LASIK reduces night vision.

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