

Efficacy of Measuring Visual Performance of LASIK Patients under Photopic and Mesopic Conditions

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Abstract

Introduction: The aim of the study was to compare the visual performance of LASIK eyes measured using high-contrast logMAR letter charts under bright (photopic) and dim (mesopic) conditions. **Materials and Methods:** A total of 46 subjects (35 ± 8 years of age) undergoing LASIK procedures were recruited for the study. The best spectacle-corrected visual acuity (BSCVA) of each subject was measured using the high-contrast ETDRS logMAR chart under photopic and mesopic conditions at 3 visits: preoperative (Pre), 1 month postoperative (Post1) and 3 months postoperative (Post3). The differences in logMAR scores for the right eyes only were analysed for the Pre-Post1 (n = 46), Pre-Post3 (n = 18) and Post1-Post3 (n = 16) comparisons. **Results:** The logMAR scores of subjects were worse at the 1-month postoperative visit than preoperatively, and improvement in visual performance was seen at the 3-month postoperative visit. These changes in visual performance became more evident under mesopic conditions. The means and standard errors of the differences in logMAR scores for the Pre-Post3 (0.097 ± 0.020) were slightly larger than those of the Pre-Post1 (-0.067 ± 0.019) and Post1-Post3 (0.031 ± 0.012) comparisons. Under mesopic conditions, the visual performance of the subjects was statistically significant for the 3 comparisons, but not under photopic conditions. **Conclusion:** High-contrast logMAR chart performed under mesopic conditions has the potential to replace visual acuity measured under photopic conditions in providing more reliable representation of postoperative visual outcomes of LASIK eyes. Eye doctors should consider performing this vision test routinely to gauge the success of LASIK surgery.

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Introduction

LASIK is routinely carried out to correct the refractive errors of myopic patients. A high percentage of patients have good high-contrast visual acuity after undergoing LASIK surgery, with the majority of them having unaided vision that meets the minimum recommended criteria for driving. Patients reported improved visual acuity under photopic conditions at 1 month postoperative visits, and others showed further improvements in visual acuity up to 12 months postoperatively.¹⁻³

Although complications related to LASIK surgeries have been relatively low, patients have been known to complain of night vision disturbances, including glare disability,

poor contrast judgements and image degradations leading to the perception of haloes and starbursts.^{4,5} In turn, night vision disturbances have a negative impact on the performance of drivers under poor and dim lighting conditions, and may pose occupational hazards for operators of vehicles like fork lifts, trains and planes. LASIK patients with poor visual outcomes have been found to correlate with small and decentred ablation zones, the occurrence of flap striae and misalignment, postoperative epithelial ingrowth, corneal asphericity changes and large pupil size in the dark.⁶⁻⁸ As such, high-contrast visual acuity of LASIK patients under photopic conditions alone would not be adequate to assess their visual performance. Contrast

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sensitivity functions of LASIK patients measured with tests such as Pelli-Robson, Regan, Vistech 6500, CSV 1000 and Stereo Optical FACT charts have showed a decrease in the ability to discriminate contrast soon after surgery, but has the potential to stage a gradual recovery a few months postoperatively.^{1,7,9}

High-contrast logMAR charts have been extensively used to measure the visual performance of subjects under photopic conditions. However, few studies have used high-contrast logMAR charts to measure the visual performance of LASIK patients under mesopic conditions. This study aims to compare the visual performance of patients using high-contrast visual acuity charts under photopic and mesopic conditions at pre- and post-LASIK surgery visits.

Materials and Methods

Subjects

A total of 46 subjects (92 eyes) who presented for LASIK surgery at a major community hospital in Singapore consented to participate after the study protocol had been explained to them. All subjects presented for a follow-up visit at 1 month post-surgery, while less than half (18 subjects) of these subjects returned for the 3-month post-surgery visit. The female-to-male ratio was 2:1, with an age range of between 22 and 49 years (mean \pm SD = 35 \pm 8 years). All subjects were Singaporeans of Chinese ethnicity, with the exception of 2 subjects of Indian ethnicity, and a Caucasian subject.

Ocular and Vision Assessment

Corneal health of the subjects was examined by 3 eye surgeons (HML, HBF, WJH) before the LASIK procedures being carried out. Subjects who displayed abnormal corneal topography mappings (indicating conditions such as keratoconus) and those with ocular diseases were excluded. The subjective refraction of each eye was then carefully performed by an optometrist to determine the correction needed for the LASIK procedures. Eight eyes had equivalent spheres of less than -3.00 DS, 44 eyes had equivalent spheres greater than or equal to -3.00DS but less than -6.00DS, and the remaining 40 eyes had equivalent spheres greater than -6.00DS. Using the best correction derived from the refraction, the following tests were used to assess the visual performance of each subject at the preoperative visit, and at the 1-month and 3-month postoperative visits:

1. Best spectacle-corrected visual acuity (BSCVA) of the high-contrast ETDRS logMAR chart under photopic conditions (70 cd/m²), and
2. BSCVA of the high-contrast ETDRS logMAR chart under mesopic conditions (1 cd/m²).

Subjects were asked to read the logMAR chart until they were no longer able to read the letters on the smallest line. The logMAR score of the subjects was recorded for the visual performance under photopic and mesopic conditions.

Data Analysis

Correlation coefficient analyses were performed using Proc Corr in SAS (SAS Institute Inc., USA) to understand the nature and strength of the association between the difference in logMAR scores measured for the left and right eyes. These analyses were performed for photopic and mesopic conditions. Differences in logMAR scores were calculated for the preoperative (Pre), 1 month postoperative (Post1) and 3-month postoperative (Post3) visits.

The differences in visual performance of the left and right eyes were not independent of each other. Pearson's analyses showed that there were statistically significant correlations for the difference in logMAR scores between the right and left eyes for Pre-Post1 and Pre-Post3 visits under both photopic and mesopic conditions. The correlation was also statistically significant for Post1-Post3 under photopic conditions. Subsequently, statistical analyses for the difference in logMAR scores between pre- and post-LASIK visits under photopic and mesopic conditions were performed using measurements taken for the right eyes only.

The measurements of visual performance of the right eyes for the Pre-Post1 LASIK (n = 46 eyes), the Pre-Post3 LASIK (n = 18 eyes) and the Post1-Post3 LASIK (n = 16 eyes) under photopic and mesopic conditions were entered into SAS for analysis. Both parametric (paired Student's *t*-test) and non-parametric (Sign test and Wilcoxon signed rank test) tests were performed using Proc Univariate with Normal Test and Plot options in SAS due to the limited number of eyes for the Pre-Post3 and the Post1-Post3 comparisons. All statistical tests were done at 5% level of significance and the data were entered into SAS 8.02 (company details and reference) for analysis.

Results

Under mesopic conditions, statistically significant differences were found in the visual performance of right eyes for all 3 comparisons: Pre-Post1, Pre-Post3, and Post1-Post3. The means and standard errors of the differences in logMAR scores for the Pre-Post1, the Pre-Post3, and the Post1-Post3 were -0.067 ± 0.019 , -0.097 ± 0.020 , and 0.031 ± 0.012 respectively. In comparison, there were no statistically significant differences in logMAR scores for the same comparisons under photopic condition. The means and standard errors of the differences in scores for the Pre-Post1, the Pre-Post3, and the Post1-Post3 were

Table 1. Parametric and Non-parametric Testing for the Pre-Post1, the Pre-Post3, and the Post1-Post3 Visits

Difference (logMAR units)	Pre - Post1		Pre - Post3		Post1 - Post3	
	Photopic	Mesopic	Photopic	Mesopic	Photopic	Mesopic
Number of observations	46	46	18	18	16	16
Mean	-0.001	-0.067	0.000	-0.097	0.018	0.031
Standard error	0.008	0.019	0.007	0.020	0.017	0.012
95% confidence interval	-0.017	-0.105	-0.015	-0.139	-0.018	0.006
	0.015	-0.029	0.015	-0.055	0.054	0.056
<i>P</i> value (2-tailed) Student's <i>t</i> -test	0.916	0.001*	1.000	0.0002*	0.309	0.021*
Sign	1.000	0.023*	1.000	0.0003*	1.000	0.006*
Signed rank	0.924	0.001*	0.971	0.0003*	0.422	0.026*

* Significant at 5% level of significance.

Table 2. Comparison of Photopic and Mesopic Postoperative Outcomes for the Pre-Post1, the Pre-Post3, and the Post1-Post3 Visits

Difference in VA (logMAR units)	Pre - Post 1 (46 Px)		Pre - Post3 (18 Px)		Post1 - Post3 (16 Px)	
	Photopic	Mesopic	Photopic	Mesopic	Photopic	Mesopic
Mean difference	0.00	-0.07	0.00	-0.10	0.02	0.03
SD	0.06	0.12	0.03	0.09	0.07	0.05
Postoperative outcomes						
Deteriorated	16	30	5	16	3	1
No change	15	2	8	1	9	4
Improved	15	14	5	1	4	11

SD: standard deviation; VA: visual acuity

Figures in bold (30, 16, 11) denote the dominant type of subjects in each of the Pre-Post1, Pre-Post3 and Post1-Post3 groups.

-0.001 ± 0.008, 0.000 ± 0.007, and 0.018 ± 0.017 respectively. Test results were supported by both parametric and non-parametric tests (Table 1).

Patients generally showed deterioration in logMAR scores 1 month after surgery (Pre-Post1) and slight improvement in acuities 2 months later (Post1-Post3). These deteriorations and improvements were more pronounced when measured under mesopic rather than photopic conditions (Table 2). This finding was supported by logMAR scores of individual eyes of subjects (Table 3). On closer inspection of individual eyes of 16 subjects who completed all 3 visits, the pattern of deterioration in logMAR scores under mesopic conditions could also be observed 1 month after surgery, followed by an improvement in acuities at 3 months postoperatively (Fig. 1). This pattern was not evident for vision tests performed under photopic conditions.

Discussion

High-contrast logMAR visual acuity of LASIK eyes measured under mesopic conditions showed that the vision chart has good efficacy in investigating visual performance

of patients. This method of vision measurement is simple and convenient to carry out in most clinical settings, and has the potential to provide reliable information about the success of LASIK procedures. It could also help LASIK surgeons to understand the complaints of patients who reported seeing poorly under dim illumination, and this carries greater importance for those who operate motor vehicles, shipping vessels and aircrafts¹⁰ under mesopic conditions.

Gauthier and co-workers¹¹ have used the high- and low-contrast ETDRS charts to measure visual performance of photorefractive keratoplasty eyes under photopic and mesopic conditions. The authors reported that the BSCVA of photorefractive keratoplasty-treated eyes were generally poorer than that of non-treated eyes, and the greatest difference was found for the low-contrast logMAR chart measured under low illumination. These findings were more pertinent for eyes with higher refractive errors, postoperative central corneal irregularities and those with subepithelial haze. Our results have reaffirmed the usefulness of testing visual performance of LASIK eyes

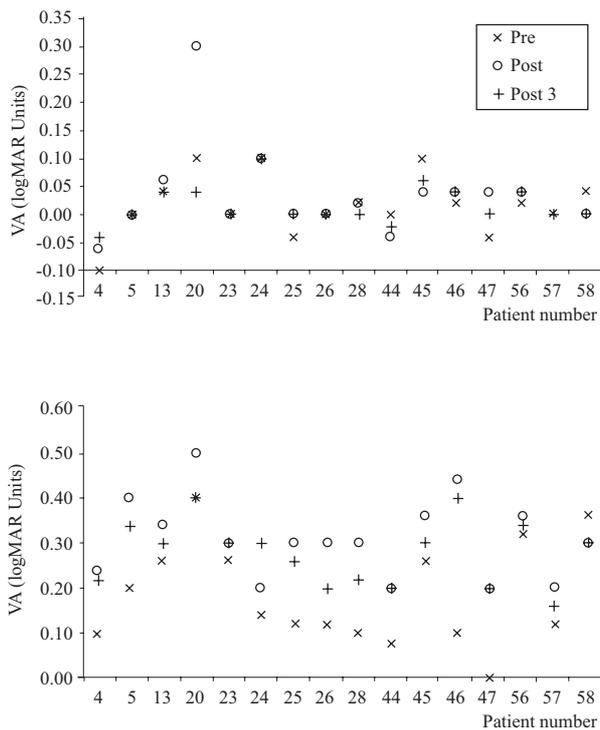


Fig. 1. The change in logMAR scores of the subjects (n = 16) at the pre-, post1 and post3 visits under photopic (top) and mesopic (bottom) conditions.

under low illumination, and may be recommended as the “minimum standard” of visual acuity assessments in LASIK eyes.

High-contrast visual acuity of LASIK patients under mesopic conditions in this study was significantly poorer at the 1- and 3-month postoperative visits than the preoperative visits. Findings from the present study were consistent with previous reports whereby there was an initial loss of visual performance under mesopic condition for LASIK eyes, and a subsequent improvement in vision several months postoperatively.¹⁻³ In comparison, visual acuity of LASIK patients under photopic conditions did not show any noticeable change at pre- and postoperative visits. This result was consistent with those reported by Montes-Mico and co-workers,⁹ who found that the contrast sensitivity functions of LASIK patients were reduced at high spatial frequencies at 6 months postoperatively, when compared with pre-surgery functions. Similarly, they reported that the contrast sensitivity of postoperative LASIK eyes under photopic conditions were not significantly different from that of preoperative eyes. Although letter targets on the logMAR chart cannot be easily separated into specific spatial frequencies, unlike the Stereo Optical FACT chart used by Montes-Mico and co-workers, the logMAR chart has the advantage of providing useful information about the ability of LASIK patients to perceive real-world targets,

Table 3. Summary of the logMAR Scores of Individual Eyes of Subjects for the Pre-, Post1 and Post3 Visits

	Photopic (logMAR units)			Mesopic (logMAR units)		
	Pre	Post 1	Pre-Post1	Pre	Post 1	Pre-Post1
n	92	92	92	92	92	92
Mean	0.02	0.02	0.00	0.19	0.26	-0.07*
SD	0.05	0.06	0.05	0.10	0.11	0.11
Max	0.20	0.30	0.14	0.40	0.58	0.22
Min	-0.10	-0.10	-0.20	0.00	0.00	-0.34
	Pre	Post 3	Pre-Post3	Pre	Post 3	Pre-Post3
n	36	36	36	36	36	36
Mean	0.02	0.02	0.00	0.18	0.27	-0.09*
SD	0.05	0.04	0.03	0.11	0.07	0.08
Max	0.10	0.10	0.12	0.40	0.40	0.06
Min	-0.10	-0.04	-0.06	0.00	0.14	-0.30
	Post1	Post 3	Post1-Post3	Post1	Post 3	Post1-Post3
n	32	32	32	32	32	32
Mean	0.03	0.02	0.01	0.30	0.27	0.03
SD	0.07	0.04	0.06	0.08	0.07	0.05
Max	0.30	0.10	0.26	0.50	0.40	0.14
Min	-0.10	-0.04	-0.10	0.20	0.16	-0.10

Max: maximum; Min: minimum; SD: standard deviation

* Deteriorations of logMAR scores found during the Post1 and Post3 visits (compared with preoperatively) under mesopic conditions

like traffic signs, under bright and dim illumination.

The high-contrast visual acuity of LASIK subjects between the preoperative and 3-month postoperative visits under mesopic conditions was significantly different in this study, indicating that the visual performance of LASIK eyes had not fully recovered to their preoperative levels after 3 months. The decrease in visual performance could be due to the higher-order aberrations present in eyes treated with refractive surgeries and when the pupils were large. Compared with LASIK eyes, Oshika and co-workers¹² reported that patients with photorefractive keratoplasty procedures suffered from lower degrees of aberrations for mesopic pupil size of 7 mm, and the impact of aberrations on visual performance was generally less with smaller pupil sizes. Measurements of higher-order aberrations in LASIK eyes were carried out for this study, and the results of the analysis will be reported separately.

The study revealed a difference between high-contrast visual performance of LASIK patients at 1- and 3-month postoperative visits. Past studies have showed that higher amount of myopic correction was related to higher incidence of visual complications, and lower satisfaction of visual outcomes.^{13,14} In this study, 40 out of 92 LASIK eyes (43%) had refractive errors greater than 6 dioptres. The recovery of postoperative visual performance of patients with high refractive errors may not be as satisfactory as those with lower amounts of myopic corrections, since more corneal tissues would have to be removed during surgery and more undesirable aberrations would be induced.¹⁵ Nevertheless, LASIK has been shown to be a better choice for correcting high myopia than photorefractive keratoplasty.¹⁶ The visual performance of some postoperative eyes in this study could also have been affected by the presence of residual irregular astigmatism.

Night vision disturbances of postoperative LASIK eyes may include a heightened sensation of glare and the perception of haloes and starbursts. Visual performance of LASIK patients can be assessed together with the use of glare sources such as the Brightness Acuity Tester (BAT)¹⁷ and the Van der Berg Straylightmeter.¹⁸ Although it would be useful to include the testing of glare sensitivity of postoperative eyes, local anecdotal evidence showed that the impact of night vision disturbances due to glare sensitivity in Singaporean patients has been minimal. This may be due to the smaller pupil sizes of ethnic Chinese population, good centration of treatment zones and the use of advanced surgical instrumentations. Careful refraction of the LASIK eyes and using BSCVA as the basis for visual performance measurements have further contributed to the good visual outcomes in this study.

There were no reported complications due to LASIK procedures such as flap misalignment, epithelial in-growth

and corneal haze for all subjects who took part in this study. This may be attributed to the use of up-to-date LASIK equipment, the skill of the surgeons who performed the procedures, and perhaps the small sample size of this study. This is also consistent with lower rates of complications related to LASIK compared with radial keratotomy and photorefractive keratoplasty procedures.^{19,20} Patients can be further reassured of safer outcomes with the introduction of precise eye trackers, laser microkeratomes and more advanced wavefront-guided LASIK instruments.^{8,21,22}

Conclusion

Evaluation of visual performance of LASIK eyes using the high-contrast logMAR chart under mesopic conditions can provide more reliable information for LASIK surgeons to determine the operative outcomes of patients than measuring high-contrast visual acuity alone under room illumination. This vision test under low illumination can be conducted in a relatively quick time and in a normal clinical setting. It should be recognised that high-contrast visual acuity of LASIK patients under photopic conditions lack the efficacy to detect changes in visual performance. Contrast sensitivity functions of LASIK patients who are engaged in visual tasks under poor and variable lighting conditions such as night driving, ship and aircraft navigation should be critically assessed.

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Competing Interests

The authors have no proprietary or commercial interest in any product mentioned or concept discussed in this article. This study did not receive any financial support from external sources.

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