



Original research

Comparison of the visual acuity after photorefractive keratectomy using Early Treatment Diabetic Retinopathy Study Chart and E-chart

Saeedeh Ghorbanhosseini ^a, Hassan Hashemi ^{a,b}, Ebrahim Jafarzadehpour ^{a,c,*}, Abbasali Yekta ^d, Mehdi Khabazkhoob ^e

^a Noor Research Center for Ophthalmic Epidemiology, Noor Eye Hospital, Tehran, Iran

^b Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, Iran

^c Department of Optometry, Iran University of Medical Sciences, Tehran, Iran

^d Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran

^e Department of Medical Surgical Nursing, School of Nursing and Midwifery, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received 24 February 2016; revised 12 April 2016; accepted 13 April 2016

Available online 12 July 2016

Abstract

Purpose: To compare the visual responses of post refractive surgery's patients using Early Treatment Diabetic Retinopathy Study Chart (ETDRS) and E-chart with and without color filters.

Methods: The uncorrected Logarithm of the Minimum Angle of Resolution Visual Acuity (LogMAR VA) of 70 patients with a mean age of 26.2 ± 3.76 years (from 19 to 34 years) who had undergone Photorefractive Keratectomy (PRK) (the range of post operation refractive error: ± 0.5 D) was measured under the light conditions of with and without asymmetrical glare by using red, green, and yellow filters and ETDRS chart and E-chart.

Results: In both light conditions of with and without glare, the mean visual acuity of the three filters in the right and left eyes was significantly better with the E-chart versus the ETDRS chart ($P < 0.0001$). Only in the glare light condition, the mean visual acuity of the left eye showed no significant difference between the two charts using the red filter ($P = 0.30$).

Conclusions: Visual acuity measurements were different with ETDRS chart and E-chart. These two charts cannot be used interchangeably. Copyright © 2016, Iranian Society of Ophthalmology. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Keywords: Visual acuity charts; Refractive surgery; Colored filters; Glare

Introduction

Visual acuity is the highest performance of the visual system and a conventional clinical index that depends on factors like luminance, contrast, spectral distribution, age, and visual

adaptation. In other words, visual acuity depends on the optical and neural functions of the eye,¹ and its simple measurement can reveal many visual disorders. On the other hand, despite new techniques and better equipment, many patients still have visual complaints after refractive surgery. Many studies have evaluated the visual function following refractive surgery and compared different surgical methods.^{2–5}

The measurement of visual acuity with different charts is one of the most common ways of the assessment of the visual function to identify visual system abnormalities like refractive errors, disorders of the ocular media, and optic nerve and visual pathway disorders. In general, the principles employed in designing the charts are based on common optical and

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper. Financial support: This project was supported by Noor Research Center for Ophthalmic Epidemiology.

* Corresponding author. Noor Research Center for Ophthalmic Epidemiology, Noor Eye Hospital, Tehran, Iran.

E-mail address: jafarzadehpour.e@iums.ac.ir (E. Jafarzadehpour).

Peer review under responsibility of the Iranian Society of Ophthalmology.

physiological parameters, and the only difference in charts is related to their design type and measurement accuracy.⁶

The E-chart and Early Treatment Diabetic Retinopathy Study (ETDRS) chart are two charts that are designed based on similar principles and a five-by-five grid pattern. The E-chart (with a design similar to the Snellen chart) is the most common chart in the world that has a big letter on top, and the number of letters increases from the top to the bottom of the chart.⁶ This chart is commonly used for the screening of visual acuity in children and assessment of visual acuity in illiterate or non-English speaking patients.⁷

One of the specifications of the E-chart is the evaluation of resolution acuity (the minimum distance between two adjacent points or lines to be recognized as two separate objects)⁸; however, this chart may have some limitations:

1. Due to the varying number of letters in the upper lines of the chart, the value of each letter in the upper lines is not similar to its value in the lower lines.⁶
2. Since the size of the letters in each line does not follow a certain order, it may lead to over estimation in the lower lines.⁶
3. There is much contour interaction in the E-chart.^{7,9}
4. The test-retest variability of the E-chart is high thereby decreasing the possibility of the accurate diagnosis of visual changes, which is important for research purposes.^{10,11}

However, other standard charts have been designed since 1993. The logarithmic ETDRS is one of these charts. This chart, with Sloan letter optotypes, is a conventional chart for research purposes worldwide which is used as a reference for comparison with other substitute charts.¹²

The ETDRS chart evaluates the recognition acuity of the individuals¹³ and has the following advantages:

1. Since the number of letters in each line is similar, each letter has the same quantitative value equal to 0.02 Logarithm of the Minimum Angle of Resolution (LogMAR).¹²
2. The distance between the letters are constant and equal to the size of the letters (about 0.1), which controls the crowding phenomenon.¹²
3. As for identification of the letters, the letters used in the chart are in an equal level.¹²

The accurate measurement of visual acuity is very important due to the increase in the prevalence of refractive surgery and dissatisfaction of some patients with their post operative visual acuity. In general, it is not very easy to assess the visual function and detect and measure subjective symptoms of the patients, especially glare symptoms, post operatively.^{14,15}

Despite the wide use of the ETDRS chart in clinical assessments of visual acuity and research projects worldwide, the E-chart is still used in a decimal (10/10), foot (20/20), or meter (6/6) scale. Since these two charts have different appearances and their results of visual acuity measurement is

different according to some studies,^{10,16–19} and because there is no clinical standard chart to measure the patients' post operative visual acuity,⁵ the question is: can the differences in the design of these two charts result in different visual acuity measurements after optical interventions on the cornea? Therefore, in this study, we used the E-chart and ETDRS chart with three color filters to measure and compare the participants' visual acuity.

Methods

In this cross-sectional study, the patients were selected from the individuals who visited Noor Eye Hospital in Iran for periodic examinations 3–11 months after Photorefractive Keratectomy (PRK) surgery for myopia or myopic astigmatism refractive error.

Exclusion criteria were any corneal pathology, glaucoma, residual refractive errors more than ± 0.5 Diopter (D) of myopia or hyperopia, residual astigmatism more than -0.75 D of with-the-rule astigmatism and more than -0.25 D of against-the-rule and oblique astigmatism, and poor understanding of English letters.

All the participants were examined in the same room. To be sure, the English letters were explained to all patients before starting the test. Since the E-chart was used to measure the visual acuity of the patients before surgery, both the E-chart and the ETDRS chart (Nidek Chart Projector, CP-770/Ophthalmic Instrument Company, Porana Business Park Unit 12/77 Porana Road, Glenfield, Auckland, New Zealand) were used at a standard distance (6 m) and in standard light conditions (BS4274) (measured by Photometer, model 606 027, Leybold Company, LD DIDACTIC GmbH Leyboldstr (Fig. 1). 1 D-50354 Hürth, Germany) to evaluate their post operative visual acuity. In all patients, the trial frame was placed in front of the eyes, and one eye was occluded at the time of examination. Uncorrected visual acuity was measured first in the right eye with two charts and then in the left eye. Both charts were randomly selected for each eye. The line assignment method was used³; the whole chart was lit, and the test continued until the patient was unable to answer more than half of the letters in a line.

Visual acuity measurements were first performed in normal light conditions without the color filters. Then, to create an asymmetrical light condition (which is more similar to natural conditions), the visual acuity was again evaluated after a halogen light source was placed on the left side of the patient (about 40 cm from the left and 46 cm from the right eye) that created a light intensity of 95 Lux in the left eye and 35 Lux in the right eye. After that, the same light conditions were used for the measurement of visual acuity using yellow (Band Pass), green (High Pass), and red (Low Pass) filters. The yellow filter used in our study was in range of 0.433 x and 0.476 y in the International Commission on Illumination (CIE) diagram measured with a spectrophotometer (Cecil-Reflectascan-ce-3055). It should be mentioned that the optical density of the three filters was similar. The filters were randomly used. To prevent adaptation to color filters, all

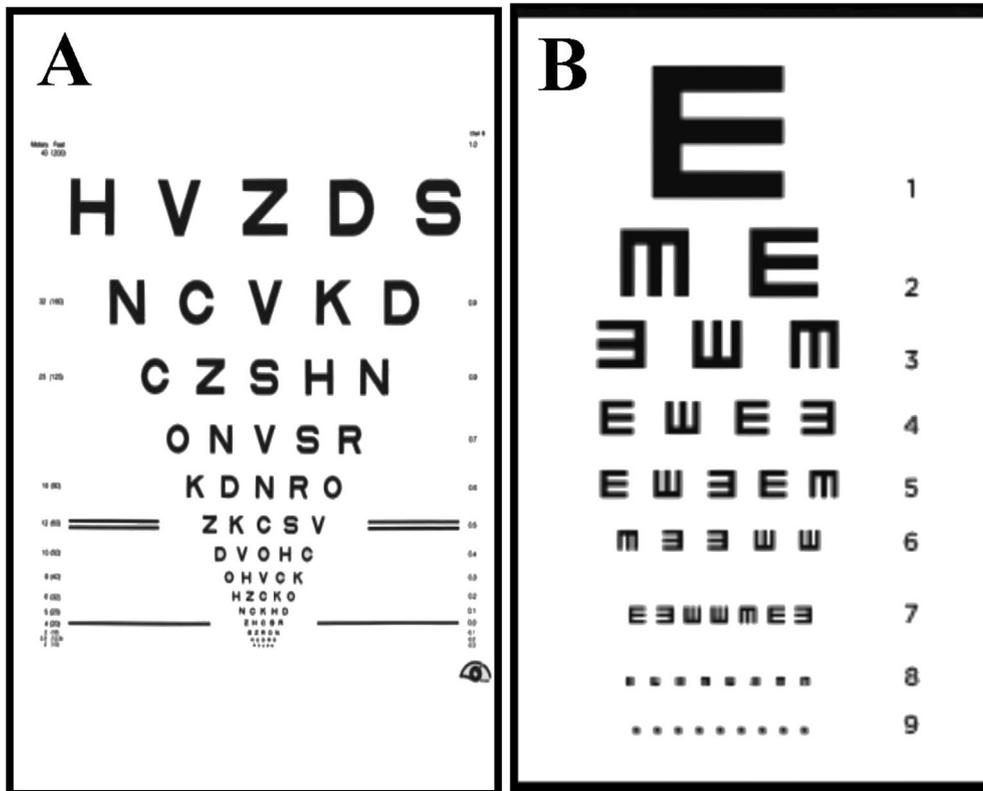


Fig. 1. Comparison of E-chart and ETDRS chart (Nidek Chart Projector, CP-770).

assessments were first performed in non-glare conditions and then repeated in glare conditions. Moreover, to prevent memorizing the letters by the participants, the questions were resumed from one upper line, and the type of the chart changed in each step of the examinations. The data was recorded in special forms, and the visual acuity measurements converted to LogMAR for statistical analysis and the paired t-test was used for data analysis. P-Value less than 0.05 was considered significant. All the participants signed the informed consents.

Results

Our study included 70 participants (140 eyes) with a mean age of 26.2 ± 3.76 years (range 19–34 years). Fourteen participants were men, and 56 (80%) were women.

The mean uncorrected visual acuity measured with the E-chart, by using three filters in both glare and non-glare conditions in each eye, was significantly better than the ETDRS chart (Tables 1 and 2, $P < 0.0001$).

The mean uncorrected visual acuity after using the red filter in glare conditions showed no significant differences between the two charts in the left eye ($P > 0.05$).

In similar light and filter conditions, the mean visual acuity of the right and left eyes compared to each other showed significant differences ($P < 0.0001$).

Table 3 presents the correlation of visual acuity of right and left eyes in E-chart and ETDRS in different light conditions.

Discussion

Visual function after refractive surgery may be affected by several factors including a rise in spherical aberration, coma and other higher order aberrations, and dry eye.^{3,4} Since the E-chart is commonly used in Iran as a visual acuity measurement tool, we decided to evaluate the quantitative difference of visual acuity measurements by ETDRS and E-chart in different light conditions using three color filters in post PRK patients.

According to the results, in most cases, i.e. in glare and non-glare conditions with all three color filters in both the right and the left eyes, the mean visual acuity measured with the E-chart was significantly better than the ETDRS chart ($P < 0.0001$) (Tables 1 and 2). This finding is very similar to the results of a study by Thorn et al in 1990²⁰ in which grating visual acuity was shown to be little affected by optical blur while the Snellen visual acuity was markedly affected by optical blur. In our study, since all optotypes in the E-chart are similar to each other and also similar to grating and because the spatial frequency changes from one line to the other, the person should only detect (resolute) the direction of the letters. On the other hand, in the ETDRS chart which contains letters, in addition to the identification of the target (resolution acuity), the person should remember the name of the target as well (recognition acuity), i.e. besides the change in the spatial frequency, visual acuity is also influenced by perception and cognition. In other words, according to this study, although little optical blur makes the person identify many target

Table 1

Comparison of uncorrected visual acuity (UCVA) between E-chart and Early Treatment Diabetic Retinopathy Study (ETDRS) chart in the right eye.

	Mean difference	Std. deviation	Range of the LogMAR (Logarithm of the Minimum Angle of Resolution). UCVA		P-value
			Lower	Upper	
E-Chart + With glare vs. ETDRS + With glare	-0.05	0.06	-0.06	-0.03	P < 0.0001
E-Chart + Without glare vs. ETDRS + Without glare	-0.06	0.06	-0.08	-0.05	P < 0.0001
E-Chart + With glare + Red filter vs. ETDRS + With glare + Red filter	-0.03	0.07	-0.05	-0.01	P < 0.05
E-Chart + Without glare + Red filter vs. ETDRS + Without glare + Red filter	-0.04	0.07	-0.06	-0.02	P < 0.0001
E-Chart + With glare + Green filter vs. ETDRS + With glare + Green filter	-0.02	0.04	-0.03	-0.01	P < 0.0001
E-Chart + Without glare + Green filter vs. ETDRS + Without glare + Green filter	-0.04	0.06	-0.05	-0.02	P < 0.0001
E-Chart + With glare + Yellow filter vs. ETDRS + With glare + Yellow filter	-0.04	0.05	-0.05	-0.03	P < 0.0001
E-Chart + Without glare + Yellow filter vs. ETDRS + Without glare + Yellow filter	-0.03	0.05	-0.04	-0.02	P < 0.0001

details, lack of accurate localization hinders the ability of the person to detect the orientation or shape of a letter in a line or its relationship with other lines.

Our results contradicted the findings of Iryna et al in 2008,¹⁸ which compared the Snellen and ETDRS charts, and also the findings of Wittich et al in 2006,¹³ which compared the ETDRS and Landolt C chart. In both studies, the visual acuity measured with the ETDRS chart (recognition ability) was better than the other chart (resolution acuity). However, it should be mentioned that these studies were conducted on patients with retinal pathologies. Iryna et al attributed the better response to the ETDRS chart to the design defects of the Snellen chart, especially in the upper lines of the chart. Wittich et al¹³ stated that when the retina was injured, the patients used

the details of the letters like the curves and diagonals, when compared to gap detection in the resolution chart, to provide better responses to the letter chart. Moreover, letters with more complex shapes facilitated the cognitive process of the brain cortex. The age range of the participants in this study was higher than our patients, and the patients had eccentric fixation due to macular problems.

Our findings were also different from the results reported by Plainis et al in 2013.²¹ They reported that letter optotypes, due to cognitive compensatory mechanisms, resulted in better vision when compared with the tumbling E-chart in normal people and that orientation identification was more difficult than letter discrimination in normal people. However, these results are not true in patients with retinal

Table 2

Comparison of uncorrected visual acuity (UCVA) between E-chart and Early Treatment Diabetic Retinopathy Study (ETDRS) chart in the left eye.

	Mean differences	Std. deviation	Range of the LogMAR (Logarithm of the Minimum Angle of Resolution). UCVA		P-value
			Lower	Upper	
E-Chart + With glare vs. ETDRS + With glare	-0.03	0.05	-0.04	-0.02	P < 0.0001
E-Chart + Without glare vs. ETDRS + Without glare	-0.04	0.05	-0.05	-0.03	P < 0.0001
E-Chart + With glare + Red filter vs. ETDRS + With glare + Red filter	-0.01	0.06	-0.02	0.01	0.30
E-Chart + Without glare + Red filter vs. ETDRS + Without glare + Red filter	-0.02	0.07	-0.04	-0.01	P < 0.05
E-Chart + With glare + Green filter vs. ETDRS + With glare + Green filter	-0.02	0.06	-0.03	-0.01	P < 0.05
E-Chart + Without glare + Green filter vs. ETDRS + Without glare + Green filter	-0.02	0.06	-0.04	-0.01	P < 0.05
E-Chart + With glare + Yellow filter vs. ETDRS + With glare + Yellow filter	-0.04	0.05	-0.05	-0.02	P < 0.0001
E-Chart + Without glare + Yellow filter vs. ETDRS + Without glare + Yellow filter	-0.03	0.05	-0.04	-0.02	P < 0.0001

Table 3
Correlation of the mean visual acuity between right and left eyes in the E-Chart and Early Treatment Diabetic Retinopathy Study (ETDRS) chart.

	Correlation coefficient	P-value
E-Chart + With glare	0.326	0.006
E-Chart + Without glare	0.352	0.003
ETDRS + With glare	0.427	<0.0001
ETDRS + Without glare	0.310	0.009
E-Chart + With glare + Red filter	0.366	0.002
E-Chart + Without glare + Red filter	0.375	0.001
E-Chart + With glare + Green filter	0.123	0.312
E-Chart + Without glare + Green filter	0.269	0.024
E-Chart + With glare + Yellow filter	0.342	0.004
E-Chart + Without glare + Yellow filter	0.373	0.001
ETDRS + With glare + Red filter	0.346	0.003
ETDRS + Without glare + Red filter	0.441	<0.0001
ETDRS + With glare + Green filter	0.266	0.026
ETDRS + Without glare + Green filter	0.259	0.031
ETDRS + With glare + Yellow filter	0.374	0.001
ETDRS + Without glare + Yellow filter	0.242	0.044

pathologies. Another interesting point in this study was that despite the similar nature of the Landolt C and tumbling E-chart, the patients responded better to the E-chart, which could be due to differences in their spatial characteristics, and since the tumbling E is similar to grating, it is less influenced by optical blur.

Some other studies have also found no clinically significant differences in the visual function when comparing visual acuity measured by recognition acuity and resolution acuity charts.^{7,22–24}

The reason why our patients had a better visual acuity with the E-chart could be evaluated from different aspects:

1. One of the reasons could be the limitation in the number of optotypes in the ETDRS versus the E-chart since the patients had a weaker chance of guessing. This finding is different from the results of a study by Dobson in 2009¹⁷ that reported that participants had a better visual acuity when using charts with fewer optotypes. However, in that study, the optotypes were different in the two evaluated charts while we used letters in both charts.
2. Since the ETDRS chart uses alphabets and maybe requires a higher cognitive level, it is more difficult to respond to it. In other words, identification of the letters of the ETDRS chart, apart from resolution acuity, required recognition acuity as well. Even if the E-chart is unclear, identification of the orientation of the letters is somehow possible for the patients, and the patients have 50% chance of guessing the orientation of the letter. Moreover, it seems that letter confusion is more apparent in letters with curved components.¹³

Although our patients were 19–34 years old and familiar with the English alphabet, it is important to retrain the patients before the test. In other words, Iranian people recognize the letter “E” as a symbol rather than a letter, a shape that has 3 limbs, and the 3 limbs can be arranged in 4 or 6 ways. However, this non-familiarity was a confounder, as well.

In our study, it was interesting that after using the red filter in glare conditions and the resulting decreased visual acuity, no significant difference was observed between the two charts in the left eye ($P > 0.05$) (Table 2) which was opposite to the results of the studies by Wittich in 2006,¹³ Peter in 2009,⁶ and Iryna in 2008.¹⁸ According to these studies, the difference between the two charts is more obvious in patients with worse visual acuity. It should be remembered that the participants had different retinal pathologies in the three studies. However, after using the red filter in glare conditions, a significant difference was observed between the two charts in the right eye ($P < 0.0001$) (Table 1).

Furthermore, in similar light and filter conditions, we found differences when comparing the mean difference of visual acuity between the left and the right eye; the mean difference in the right eye was 0.01–0.02 LogMAR better than the left eye in most conditions ($P < 0.0001$), which could be due to eye dominance. In general, the visual cortex neurons do not receive similar input from both eyes, and the dominant eye transfers more data to cortex layers and has a priority in visual processing and cognition.²⁵ Some studies have also shown that the right eye is dominant in most people,^{26,27} which is why the patients had a better visual acuity in the right eye in most conditions.

In summary when the participants experienced similar light conditions and visual adaptability, they had a better visual acuity with the E-chart versus the ETDRS chart. This result was obtained in Iranians as non-English speakers, which could be due to easier prediction of the letters and their orientation rather than their perception. Changes in the spectral and light conditions had no apparent effects on their perception, which is of clinical importance.

References

1. Shi W, Lockhart TE, Arbab M. Tinted windshield and its effects on aging drivers' visual acuity and glare response. *Saf Sci.* 2008;46:1223–1233.
2. Kalyvianaki MI, Kymionis GD, Kounis GA, Panagopoulou SI, Grentzelos MA, Pallikaris IG. Comparison of Epi-LASIK and off-flap Epi-LASIK for the treatment of low and moderate myopia. *Ophthalmology.* 2008;115:2174–2180.
3. Almahmoud T, Munger R, Jackson WB. Effects of advanced surface ablations and intralase femtosecond LASIK on higher order aberrations and visual acuity outcome. *Saudi J Ophthalmol.* 2011;25:275–280.
4. Slade SG, Durrie DS, Binder PS. A prospective, contralateral eye study comparing thin-flap LASIK (sub-Bowman keratomileusis) with photorefractive keratectomy. *Ophthalmology.* 2009;116:1075–1082.
5. Serrao S, Lombardo G, Ducoli P, Lombardo M. Optical performance of the cornea six years following photorefractive keratectomy for myopia. *Invest Ophthalmol Vis Sci.* 2011;52:846–857.
6. Kaiser PK. Prospective evaluation of visual acuity assessment: a comparison of snellen versus ETDRS charts in clinical practice (An AOS Thesis). *Trans Am Ophthalmol Soc.* 2009;107:311–324.
7. Kalpana S, Karthick J, Jayarajini S. Comparison of static visual acuity between Snellen and Early treatment diabetic retinopathy study charts. *Int J Educ Res Dev.* 2013;2:82–88.
8. Reich LN, Ekabutr M. The effects of optical defocus on the legibility of the Tumbling-E and Landolt-C. *Optom Vis Sci.* 2002;79:389–393.
9. Flom MC, Heath GG, Takahashi E. Contour interaction and visual resolution: contralateral effects. *Science.* 1963;142:979–980.

10. Laidlaw DA, Abbott A, Rosser DA. Development of a clinically feasible logMAR alternative to the Snellen chart: performance of the “compact reduced logMAR” visual acuity chart in amblyopic children. *Br J Ophthalmol*. 2003;87:1232–1234.
11. Rosser DA, Laidlaw DA, Murdoch IE. The development of a “reduced logMAR” visual acuity chart for use in routine clinical practice. *Br J Ophthalmol*. 2001;85:432–436.
12. Bennett AG. Ophthalmic test types. A review of previous work and discussions on some controversial questions. *Br J Physiol Opt*. 1965;22: 238–271.
13. Wittich W, Overbury O, Kapusta MA, Watanabe DH. Differences between recognition and resolution acuity in patients undergoing macular hole surgery. *Invest Ophthalmol Vis Sci*. 2006;47:3690–3694.
14. Subramanian PS, O’Kane B, Stefanik R, et al. Visual performance with night vision goggles after photorefractive keratectomy for myopia. *Ophthalmology*. 2003;110:525–530.
15. Haw WW, Manche EE. Visual performance following photoastigmatic refractive keratectomy: a prospective long-term study. *J Cataract Refract Surg*. 2000;26:1463–1472.
16. Ruamviboonsuk P, Tiensuwan M, Kunawut C, Masayaanon P. Repeatability of an automated Landolt C test, compared with the early treatment of diabetic retinopathy study (ETDRS) chart testing. *Am J Ophthalmol*. 2003;136:662–669.
17. Dobson V, Clifford-Donaldson CE, Miller JM, Garvey KA, Harvey EM. A comparison of Lea Symbol vs ETDRS letter distance visual acuity in a population of young children with a high prevalence of astigmatism. *J AAPOS*. 2009;13:253–257.
18. Falkenstein IA, Cochran DE, Azen SP, et al. Comparison of visual acuity in macular degeneration patients measured with snellen and early treatment diabetic retinopathy study charts. *Ophthalmology*. 2008;115:319–323.
19. Fan-Paul NI, Li J, Miller JS, Florakis GJ. Night vision disturbances after corneal refractive surgery. *Surv Ophthalmol*. 2002;47:533–546.
20. Thorn F, Schwartz F. Effects of dioptric blur on Snellen and grating acuity. *Optom Vis Sci*. 1990;67:3–7.
21. Plainis S, Kontadakis G, Feloni E, et al. Comparison of visual acuity charts in young adults and patients with diabetic retinopathy. *Optom Vis Sci*. 2013;90:174–178.
22. Kuo HK, Kuo MT, Tiong IS, Wu PC, Chen YJ, Chen CH. Visual acuity as measured with Landolt C chart and Early Treatment of Diabetic Retinopathy Study (ETDRS) chart. *Graefes Arch Clin Exp Ophthalmol*. 2011; 249:601–605.
23. Raasch TW, Bailey IL, Bullimore MA. Repeatability of visual acuity measurement. *Optom Vis Sci*. 1998;75:342–348.
24. Becker R, Teichler G, Graf M. Comparison of visual acuity measured using Landolt-C and ETDRS charts in healthy subjects and patients with various eye diseases. *Klin Monbl Augenheilkd*. 2011;228:864–867.
25. Shneur E, Hochstein S, eds. *Effects of Eye Dominance in Visual Perception*. International Congress Series. Elsevier; 2005.
26. Railo H, Tallus J, Hamalainen H. Right visual field advantage for perceived contrast: correlation with an auditory bias and handedness. *Brain Cogn*. 2011;77:391–400.
27. Samarawickrama C, Wang JJ, Huynh SC, et al. Macular thickness, retinal thickness, and optic disk parameters in dominant compared with nondominant eyes. *J AAPOS*. 2009;13:142–147.