

Objective Evaluation of Night Visual Distortion

a report by

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Corneal refractive surgery is a safe mode of vision correction, but a variety of complications have been described in the literature.¹ Many of these complications do not compromise the integrity of the cornea, but can cause serious visual distortions, and some of them cannot be re-treated with surgery or compensated with spectacles. Complaints of poor night vision are among the most common complaints described by patients.² Haloes are among the most commonly reported symptoms, particularly after laser-assisted *in situ* keratomileusis (LASIK) surgery,³ and a certain increase in the halo disturbance index can be present even when the procedure is considered entirely successful.^{4,5} However, other types of visual distortion can be present after corneal refractive surgery, including glare, starburst, hazy vision, monocular diplopia and polyopia, simultaneous vision and defocus.⁶⁻⁸ Such problems are primarily due to light scatter through tissues with compromised transparency, or different refraction through operated, non-operated and transition zones. With current refractive surgical procedures, the optical aetiology is the most commonly accepted source of visual distortion and several aberration

coefficients are more highly correlated with these symptoms, particularly spherical aberration.⁵

Multiple factors seem to predispose to problems of vision after refractive surgery, including attempted refractive correction, age and post-refractive surgical refraction.^{9,10} Surprisingly, pupil size and pre-surgical corneal curvature are not considered significant predictors of post-surgical visual complaints under scotopic conditions.¹¹

Even today, after years of debate, the disagreement between the patient's self-reported symptoms and the objective visual assessment as measured by the surgeon under photopic conditions causes frustrations for both patient and surgeon. The former cannot vocally express what she/he actually feels, and the latter cannot obtain objective measures of such complaints. Therefore, it is urgent to find an objective measuring method to characterise the subjective symptoms of night-vision distortion. One attempt to do so is the method described by Lackner et al.⁸ using a commercial computer program. Using this instrument, the authors evaluated the size of the halo in a longitudinal fashion from pre-surgery to six months post-surgery under mesopic conditions. This method consists of the subjective assessment of the patient by moving a stimulus from the periphery of clear vision up to what he/she judges as the limit of the halo, and has shown good repeatability on measuring halo size in patients with multifocal intraocular lens implantation given a value of the halo diameter. The main drawback is that if a defined halo is not seen or the patient does not understand what a halo really is, the patient could have difficulties in identifying the limit of clear and handicapped fields of vision. Moreover, the luminous distortions are not rotationally symmetrical in many cases, which can cause even more confusion to the patient when asked to delimitate the margin of the distortion. The fact that the stimulus is moved from the periphery to the centre after the patient has seen the stimulus could cause some problems with fixation to the central point; however, this has not been quoted as a problem by the authors. Finally, this method does not allow the differentiation of the area of the visual field where the patient is 'blind' to visual stimuli, because the patient is asked to delimitate the margin of the halo, but he/she could see the stimulus even inside this limit.

Gutierrez et al.⁴ developed a device that allows an objective index of visual disturbance of a source of light under mesopic conditions to be taken. These studies^{4,5} have brought into the clinical field an instrument that allows an objective evaluation beyond a subjective description of the visual complaints of patients and has received positive feedback.⁶ During this procedure, the patient is asked to respond when the peripheral stimuli not covered by the distortion of a bright central source of light is seen under mesopic conditions to delimitate the margins of the visual distortion, caused by the distorted optics of the eye in some conditions. The following section explains the function of this instrument in more detail.

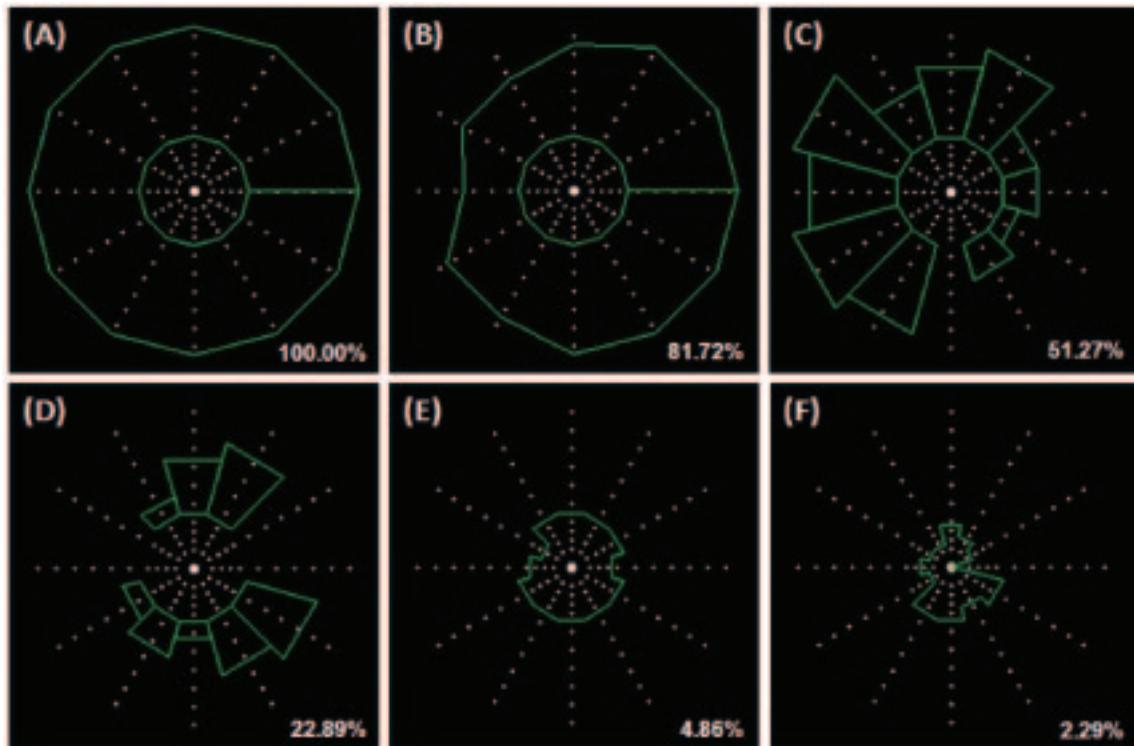
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Figure 1: Results Illustrating Different Degrees of Disturbance Measured with the Starlights



A, B: small optic zone with myopic ablation; C, D: decentred myopic ablation; E: contact lens (CL) fitting post-laser-assisted in situ keratomileusis (LASIK) with 100% index of disturbance before rigid gas permeable CLs were fitted; E: post-LASIK with 22.89% index of disturbance before fitting with soft contact lens with 3.5mm artificial pupil.

Device Description

The Starlights system (Novosalud, Valencia) consists of a black screen with a central light, which acts as a fixation stimulus and source of light. This stimulus subtends at an angle of 0.34° (1.2cm) and is surrounded by white light-emitting diodes (LEDs) distributed radially along 12 semi-meridians with a maximum amplitude of 30° ; each of them subtends at an angle of 0.06° at a distance of 2.5m between the observer and the screen. At this distance and with the room in total darkness, the luminance is about 0.17lux or $0.054\text{cd}\cdot\text{m}^{-2}$, which is slightly above the scotopic level of luminance (10^{-6} to $10^{-3}\text{cd}\cdot\text{m}^{-2}$), but is still in the range of what could be considered night vision (10^{-4} to $10^{-1}\text{cd}\cdot\text{m}^{-2}$). Exposure time (ON period) was 0.25 seconds and time between stimuli (OFF period) was one second. The instrument's set-up allows the examination time to be shortened compared with definitions used in previous studies,⁴ although it is not expected that this could affect the reliability of the examination. The device provides an index of light disturbance called the 'halo disturbance index'. However, it is not easy to isolate the halo phenomenon from other concurrent sources of distortion, and Klyce has proposed the term 'light distortion index' instead of 'halo disturbance index'.⁶ This parameter represents the percentage of the total area explored where the peripheral stimuli are not seen due to the light distortion induced by the central source on the patient's retina under scotopic conditions. The total area can be taken as the inner circle or the peripheral circle depending on the severity of the distortion. Some examples of results obtained with the Starlights are shown in Figure 1. Further descriptions of the instrument can be found in previously published work.^{4,5}

Factors Affecting Results

The set-up of the experiment is important in order to obtain reproducible results. In this regard, the intensity, size and position of the peripheral stimuli should be maintained constant in successive examinations. The software

allows adjustment of these parameters, warranting good levels of repeatability and reproducibility in normal and operated patients.⁴ The patient's distance from the screen, alignment with the central stimulus and head stability are also crucial factors. Room illuminance and screen luminance (for central fixation target and peripheral stimulus) should also be accurately calibrated and replicated among measuring sessions, particularly in longitudinal follow-up. Results from the Starlights system seem not to be affected by the type of refractive status, with no significant differences between emmetropic and ametropic patients with different refractive conditions. The form of correction, i.e. contact lenses or spectacles, did not have a significant effect on the results of Starlights either.⁴

Current and Potential Applications

The most immediate application for this technique is in the field of refractive surgery, as the instrument provides a new standard of measurement for the assessment of the quality of vision before and after refractive surgical interventions.⁵ The other major role for this technique is the objective evaluation of visual complaints reported by some patients after refractive surgery, orthokeratology and intraocular lens implantation in order to corroborate and quantify the problem, and to measure the potential benefit of different strategies to reduce the symptoms. Different studies conducted by our group have evaluated the sensitivity of the Starlights to detect differences in visual distortion in post-LASIK patients. This experiment was part of the instrument's evaluation and represented that LASIK patients showed higher index of visual distortion than age-matched normal patients.⁴ As a result of these findings, a new study was developed in order to evaluate the impact of fully successful LASIK surgery on visual distortion under scotopic conditions measured with Starlights. This study showed that even in those subjects considered entirely successful there was an increase in the disturbance index. Interestingly, this increase was not correlated with pupil

Figure 2: Visual Distortion Under Mesopic Conditions

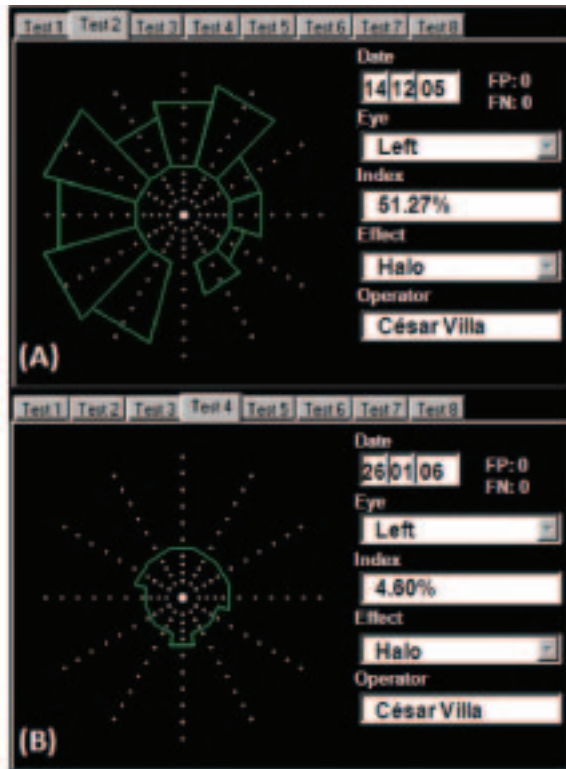


Figure shows a patient with poor night vision after laser-assisted in situ keratomileusis refractive surgery. A: represents visual distortion under mesopic conditions before contact lens (CL) fitting; B: after CL fitting.

size, but with the higher order aberration (HOA) of the anterior corneal surface, namely spherical aberration, coma and secondary astigmatism.⁵ Using the same apparatus, Jimenez et al. detected a linear decrease in the binocular summation of index of disturbance (defined as the binocular disturbance index/mean monocular disturbance index) as the asymmetry in HOA root mean square (RMS) increased after LASIK surgery. This study revealed that anisometropic LASIK will reduce the quality of vision expressed by contrast sensitivity function (CSF), HOA and night visual distortion measured with the Starlights halometer.¹²

However, in addition to the diagnostic role of the instrument, it is also useful as follow-up when actions to improve night vision in post-surgical corneas are taken. Different approaches have been proposed to minimise visual distortions after refractive surgery, surgical re-treatments to enlarge the optical zone,¹³ overcompensating the optical prescription and miotic

drugs.^{7,14} The remaining solutions are not practical and are not commonly used in the clinic, except when re-treatment is an option and new laser algorithms have demonstrated good results.¹⁵ Post-surgical contact lens (CL) fitting is the choice when re-treatment is not possible due to the patient's choice or surgeon's criteria. At this stage, multiple solutions are available, including the creation of artificial pupils with cosmetic CLs or rigid gas permeable (RGP) CL in conventional or reverse geometry designs. In a report of 29 fittings by Alio et al.,¹⁶ almost 75% of cases were fitted with RGP or hybrid CL, showing a gain in visual acuity from 0 to 9 lines over best-corrected visual acuity (BCVA) with spectacles. Reverse geometry soft CL are also available. However, the CL option is not always welcomed by the patient because of previous experience, with or without good tolerance, with this type of correction. The objective measurement of visual benefit will help to improve awareness of patients of the actual benefit of the CL fitting, and enhance our understanding of visual rehabilitation after post-surgical complications with refractive surgery.

In a series of cases followed at our clinic, visual acuity improved significantly after CL fitting in complicated LASIK surgery. However, most importantly, symptoms of night vision disturbance significantly improved, and this was accompanied by a reduction in the visual disturbance measured with the Starlights, and wavefront aberration reduction supported these findings (submitted for publication). Figure 2 shows an example of change in visual distortion before and after RGP CL fitting in a complicated LASIK case.

Other potential fields of application could be the evaluation of mesopic and scotopic vision with multifocal intraocular lenses and CLs. It is well known that these systems induce significant changes in the aberration structure of the eye, causing symptoms similar to those reported by post-LASIK patients, as 'ghost' images and haloes. Other similar instruments have been used for this purpose.¹⁷ The evaluation of the impact of other refractive therapies such as overnight orthokeratology or corneal refractive therapy on night visual distortion will also benefit from this kind of instrumentation.

In summary, Starlights objectively measures the distortion induced by the optics of the eye on seeing a bright light source. This parameter seems to be representative of the subjective complaints of patients after refractive surgery, and it can be used as diagnostic and follow-up tool in patients who are going to be compensated with CLs or other strategies to improve night vision. The apparatus has potential in other areas as multifocal compensation with intraocular lenses and CLs, as well as in the field of corneal refractive therapy. ■

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