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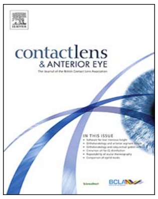

Disability glare in soft multifocal contact lenses

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ABSTRACT

Purpose: The study investigated the effect of the design of multifocal contact lenses on the sensitivity to contrast and disability glare.

Methods: Contrast sensitivity was measured in 16 young adults (mean age: 25.5 ± 2.5 years) at a distance of 2 m under two conditions: no-glare and glare. Two designs (Center Near and Center Distance) of the Biofinity soft contact lens were used to simulate correction for presbyopes, while a correction with single vision trial lenses and contact lenses acted as controls.

Results: The design of the used multifocal contact lenses had a significant influence on the log area under the curve of the contrast sensitivity function (AUC-CSF). Compared to the spectacle lens correction, the AUC-CSF was significantly reduced, in case CS was measured with the Center Near design lens, under the no-glare ($p < 0.001$) and the glare condition (p: $p < 0.001$). In case of the Center Distance design contact lens, the AUC-CSF was significantly smaller in case CS was tested under glare ($p = 0.001$). Disability glare (DG) was depending on the spatial frequency and the design of the multifocal lens, while the Center Distance design produced higher amounts of DG ($p < 0.001$), compared to the other used corrections.

Conclusion: The optical design of a multifocal contact lenses has a significant impact on the contrast sensitivity as well as the disability glare. In order to dispense the best correction in terms of contact lenses, the sensitivity to contrast under no-glare and glare conditions should be tested a medium spatial frequencies.

1. Introduction

The achieved quality of vision with any method that is used to correct refractive errors, such as spectacle lenses, contact lenses or intraocular lenses, is of major importance for the success of these methods. While the correction of refractive errors with single vision solutions especially in the pre-presbyopic age normally results in a good visual performance, the use of a bifocal or multifocal contact lens correction for presbyopes can reduce the sensitivity to contrast (CS) [1,2], especially under the influence of glare [3] and wearers also experience ghost images [4] or haloes [5]. The visual performance with or without the correction of refractive errors is measured in means of the high contrast visual acuity, but it is often reported that this single measure is not a good indicator for the quality of vision [6,7]. Therefore, it is recommended that this measurement is accompanied by the measurement of the CS, either at a limited number of spatial frequencies or by the assessment of the contrast sensitivity function (CSF) that also describes the cut-off spatial frequency. Additionally, such measurement can be done with and without the presence of glare in order to measure the so called disability glare [8] or to describe the level of intraocular scatter [9]. It is also of great importance if the described and reported disadvantages of such a solution affect the quality of vision in the population that is targeted with this solution. Various studies have been conducted that described the sensitivity to contrast with various types of bifocal or multifocal contact lenses. When various indicators of the visual performance (high and low contrast visual acuity, disability glare, contrast sensitivity) were compared between different multifocal CLs (gas-permeable multifocal & soft bifocal contact lenses), Rajagopalan [2] reported an increased sensitivity to glare with such corrections, but high binocular contrast sensitivity and sufficient high as well as low contrast visual acuity. The same authors concluded that the measurement of sensitivity to contrast and glare should be included into the fitting process of such lenses. Only recently, the influence of multifocal contact lenses on the intraocular scatter as well as the disability glare became of interest. Grzegorz and colleagues [10] measured an increase in straylight and light scatter with multifocal contact lenses when compared to measurements without the contact lens that acted as a control. In their study, the authors used different

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contact lenses from different manufacturers. It is also of interest, if the design of a multifocal contact lens itself has a direct impact on the contrast sensitivity and the disability glare. Therefore, the aim of the current study was to investigate the influence of the design of a commercially available contact lens with two variations in their optical design (Center-Near design and Center-Distance design) on the contrast sensitivity when measured with and without glare.

2. Methods

2.1. Participants

The study was approved by the Institutional Review Board of the Medical Faculty of the University of Tuebingen and the study protocol was in accordance with the Declaration of Helsinki. All subjects provided their signed consent, after the study protocol was explained, including the explanation of the nature and possible consequences of the study. In total, 16 subjects with a mean age of 25.5 ± 2.5 years and a mean spherical equivalent refractive error (SE) of -3.5 ± 4.0 D and a mean astigmatism of -0.75 ± 0.5 (range: -0.25D to -2.00D) participated.

2.2. Study protocol

In each subject, the pupil of the dominant eye was dilated and accommodation was paralyzed during the course of the study, using three drops of a cycloplegic agent (1% cyclopentolate hydrochloride; Alcon Ophthalmika GmbH, Austria). Refractive errors were measured prior to the experiment, objectively (ZEISS i.Profiler plus, Carl Zeiss Vision Gmbh, Aalen, Germany) and subjectively (ZEISS Subjective Refraction Unit, Carl Zeiss Vision Gmbh, Aalen, Germany). Correction of subjectively measured refractive errors was achieved, while the rule “maximum plus with highest visual acuity” was followed and a trial frame and trial lenses were used for the correction. All subject were wearing the following types of the Biofinity soft contact lens (Cooper Vision, Victor, USA) with a distance spherical power of 0.25D: single vision (SVL), Center-Near Design (CND) and Center-Distance Design (CDD), both with an additional power of 2.5D. An artificial pupil with a diameter of 5 mm was placed into the trial frame during the course of the study in order to assure the same pupil size between the subjects. Push-up measurements from first clear to first noticeable blur in the distal and proximal direction were performed before, in between, and after the course of the experiment to control the paralyzation of the accommodative system [11].

2.3. Measurement of contrast sensitivity and assessment of disability glare

The Tuebingen Contrast Test (TueCST) [12] was used to measure contrast sensitivity at spatial frequencies of 1, 3, 6, 12, 18, 24 and 30 cycles per degree, under no-glare and glare conditions. In case of measurements under glare, a uniform and bright annulus (luminance: 270 cd/m^2) was shown concentrically around the Gabor Patches (luminance: 40 cd/m^2) that were used as stimuli for the CS measurements. A 4-AFC paradigm with 40 trials was used to find the contrast threshold for each spatial frequency, while the presentation of the different spatial frequencies was randomized. The Gabor Patches were displayed on a LCD Display (ViewPixx 3D, VPixx Technologies, Saint-Bruno, Canada) with a 16 bit grey-resolution and a pixel resolution of 1920 × 1080. A luminance meter (Konica Minolta LS-110, Konica Minolta Inc., Tokyo, Japan) was used to control gamma correction and luminance. The contrast sensitivity was measured with all contact lenses as well as with the trial frame correction, while the test order was individually randomized for each subject. The test distance was 2 m and the subjects head was fixed, using a chin- and headrest. Prior to each measurement, with each of the contact lenses as well as with the trial frame, the best (most positive) spherical focus was subjectively determined for the test distance of 2m, while an acuity chart was displayed on the monitor and trial lenses were used to achieve the highest visual acuity. As described by Aslam, the reduction of the retinal image contrast due to intraocular light scatter, or straylight is defined as disability glare [13]. The disability glare (DG) was calculated for each single spatial frequency using the formula: $DG = \log CS_{off} - \log CS_{on}$, whereas $\log CS_{off}$ is the logarithmic contrast sensitivity without glare and $\log CS_{on}$ is the logarithmic contrast sensitivity under glare [8].

2.4. Statistics

MS Excel (Microsoft Corporation, Redmond, Washington, USA) and Matlab 2016b (The MathWorks Inc., Natick, Massachusetts, USA) were used for data processing and calculation. SPSS statistics 24 (International Business Machines Corp., Armonk, New York, USA) was used for the statistical analysis (ANOVA, Post-hoc analysis, Bonferroni correction).

3. Results

3.1. Contrast sensitivity and area under the curve of the contrast sensitivity function

First of all, it was of interest, if there was an influence of the different types of corrections on the contrast sensitivity function. To compare the measured contrast sensitivity function, the area under the curve of the logarithmic contrast sensitivity function (AUC-CSF) [14] was used for the statistical analysis. The mean AUC-CSF ± 1 standard deviation, when calculated for all types of corrections and for the measurements with and without glare, can be obtained from Table 1.

The contrast sensitivity functions and the difference between the CSF for the four different corrections are shown in Fig. 1 (Fig. 1a: CSF without glare, Fig. 1b: CSF when measured under glare, Fig. 1c: difference in CSF between the two glare conditions) (Table 2).

The shape of the CSF (with or without glare) followed the typical form of the CSF, where CS is highest at medium spatial frequencies and started to decrease with increasing spatial frequencies. As expected, the CSF as well as the AUC-CSF was highest for the trial frame and single vision contact lens correction. Bonferroni corrected post-hoc analysis of the ANOVA identified no significant differences in regards of the AUC-CSF between the trial frame correction and the correction with the single vision contact lens, either under the no-glare condition ($p = 1.0$) nor under the glare condition ($p = 1.0$). A two-factor ANOVA (type of correction, test condition) revealed a significant influence of the type of correction on the AUC-CSF ($F(3120) = 25.841$, $p < 0.001$). For the trial frame correction, Post hoc analysis (Bonferroni corrected) found significant differences of AUC-CSF under both conditions (no glare, glare) when compared to the Center-Near design contact lens (no glare: $p < 0.001$, glare: $p < 0.001$). For the Center-Distance contact lens, the AUC-CSF was significantly different to the trial frame correction,

Table 1
Mean AUC-CSF ± 1 standard error of the mean for the four different types of corrections under the no-glare and glare conditions.

	Trial frame	SV contact lens	Center-Near Design contact lens	Center-Distance Design contact lens
AUC-CSF/ no-glare	21.78 ± 1.26	20.92 ± 1.25	11.92 ± 1.07	17.58 ± 1,34
AUC-CSF/ glare	19.01 ± 1.65	18.15 ± 1.43	8.66 ± 1.05	11.29 ± 1.33