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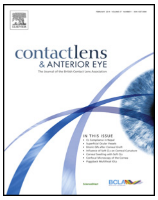

Peripheral refraction with eye and head rotation with contact lenses

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ABSTRACT

Purpose: To evaluate the impact of eye and head rotation in the measurement of peripheral refraction with an open-field autorefractometer in myopic eyes wearing two different center-distance designs of multifocal contact lenses (MFCLs).

Methods: Nineteen right eyes from 19 myopic patients (average central $M \pm SD = -2.67 \pm 1.66$ D) aged 20–27 years ($\text{mean} \pm SD = 23.2 \pm 3.3$ years) were evaluated using a Grand-Seiko autorefractometer. Patients were fitted with one multifocal aspheric center-distance contact lens (Biofinity Multifocal D$^{®}$) and with one multi-concentric MFCL (Acuvue Oasys for Presbyopia). Axial and peripheral refraction were evaluated by eye rotation and by head rotation under naked eye condition and with each MFCL fitted randomly and in independent sessions.

Results: For the naked eye, refractive pattern (M, J0 and J45) across the central 60° of the horizontal visual field values did not show significant changes measured by rotating the eye or rotating the head ($p > 0.05$). Similar results were obtained wearing the Biofinity D, for both testing methods, no obtaining significant differences to M, J0 and J45 values ($p > 0.05$). For Acuvue Oasys for presbyopia, also no differences were found when comparing measurements obtained by eye and head rotation ($p > 0.05$). Multivariate analysis did not showed a significant interaction between testing method and lens type neither with measuring locations (MANOVA, $p > 0.05$). There were significant differences in M and J0 values between naked eyes and each MFCL.

Conclusion: Measurements of peripheral refraction by rotating the eye or rotating the head in myopic patients wearing dominant design or multi-concentric multifocal silicone hydrogel contact lens are comparable.

1. Introduction

Peripheral refraction has been studied extensively since it was suggested that it might play a role in the refractive development of the eye, particularly, in myopia progression [1,2]. Researchers have observed that the peripheral refraction was relatively more hyperopic in myopic eyes than in emmetropic eyes along the horizontal visual field [3]. There are also differences in the peripheral refraction and retinal contour between progressing and stable myopes [4]. A previous animal study reported that peripheral hyperopic defocus (behind the retina) could induce central myopic development [5].

Myopia correction with conventional spectacles may increase relative peripheral hyperopic defocus [6,7], especially in high degrees of myopia and at larger eccentricities of the visual field [8]. Considering the evidence that orthokeratology slows myopia progression [9–14] and that this treatment induces a substantial change in the peripheral refractive error [15] of the myopic eye toward high degrees of peripheral myopic defocus and astigmatism, a link has been suggested between relative peripheral hyperopic defocus and myopia progression in humans [9,11]. Some ophthalmic lenses [7] and contact lenses [16] have been designed specifically to arrest myopia progression based on this hypothetical mechanism. The main goal of the commercially available center-distance design multifocal contact lenses (MFCLs) is to compensate for presbyopia. However, considering the similar change in the peripheral refractive pattern induced by these lenses [17–19], it has been hypothesized that such designs can be useful to slow myopia progression [20]. Bifocal contact lenses for presbyopia have previously been used to slow myopia progression [21,22]. Recently, a

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dual-focus contact lens has been proved to be effective in reducing myopia progression by up to 34% in children over a 10-month period [23]. Kollbaum et al. recently evaluated the quality of vision of center-distance design and bifocal contact lenses for presbyopia and compared them to dual-focus lenses to determine the potential use of such lenses to control myopia [24]. Although not all of these devices are intended to induce peripheral myopic defocus, it might be of interest to evaluate the potential contribution of this factor with each lens design. However, when evaluating the potential of different multifocal devices for changing the peripheral myopic refractive pattern with contact lenses on the eye, ocular and head rotation might be a concern. Seidemann et al. [25] hypothesized that pressure exerted by the extraocular muscles and the eyelids on eye rotation might distort the shape of the eyeball and alter refraction across the visual field. However, Radhakrishnan and Charman reported that for the naked eye this might not be relevant [26]. This might be potentially different with a contact lens in place considering the effect of decentration during peripheral gaze. However, this effect remains controversial, and several authors have preferred to measure the peripheral refraction by rotating the head [16,27,28], while others performed such measurements with eye rotation [29,30].

The current study was conducted to evaluate the effect of ocular and head rotation on the peripheral refraction measurements obtained with an open-field autorefractor in myopic eyes using two different center-distance designs of MFCLs comprising an aspheric multifocal design and a concentric multifocal design.

2. Methods

The experiments were conducted at the Clinical and Experimental Optometry Research Lab (CEORLab, Minho University, Braga, Portugal). All participants were fully informed about the purpose and procedures of this study and provided written consent. The study followed the tenets of the Declaration of Helsinki; the Scientific Committee of the School of Sciences of Minho University (Portugal) approved the research protocol.

Nineteen healthy young subjects were recruited from a university population. Inclusion criteria required that patients had 20/20 monocular visual acuity, myopia lower than −8.00 diopters (D), astigmatism lower than −1.00 D as measured by subjective refraction, no ocular disease or injury, no history of refractive surgery, and no use of ocular or systemic medication.

2.1. MFCLs

The right eyes of the participants were fitted randomly in independent sessions with two MFCLs that included a distance vision zone with their foveal refractive correction. The Biofinity® Multifocal D (Comfilcon A, Coopervision, Pleasanton, CA, USA) is a new multifocal contact lens with an optical design and fitting procedure similar to those of the Proclear Multifocal D (Omafilcon A, Coopervision, Pleasanton, CA, USA). The Biofinity D lens has an aspheric center-distance multifocal design with more positive power in the outer zone of the lens. The optical design consists of a spherical central zone of 2.3 mm in diameter dedicated to distance vision, surrounded by an annular aspheric zone of 5.0 mm (1.35 mm width) of increasing addition power and a spherical annular zone of 8.5 mm (1.50 mm width) reaching the maximum add power. The second lens, the Acuvue® Oasys for Presbyopia (Senofilcon A, Johnson & Johnson, Jacksonville, FL, USA), has a multi-concentric design with center-distance area of about 2.0 mm followed by multiple alternating near and distance concentric zones (between 0.5 and 1.0 mm width) from the center to the end of the optical zone at 8.0 mm. The maximal add power in both MFCLs was +2.50 D to guarantee that equivalent add powers were available in both lenses, and the add power was closer to the one that yielded the best peripheral myopic defocus effect with the Proclear D lens in our previous study [19]. After a previous fitting session during which the optimum centration (less than 0.5 mm of lateral displacement against the limbal area) and movement (lag < 0.5 mm on lateral and upgaze) were assessed.

2.2. Central and peripheral refraction

The non-cycloplegic objective refraction was obtained in the right eye using an open-field autorefractor/keratometer Grand-Seiko WAM-5500 (Grand Seiko Co., Ltd., Hiroshima, Japan) previously used to measure the central and peripheral refractions [31,32]. The illumination in the examination room was adjusted to obtain sufficiently large pupils to facilitate peripheral measurements. The central and peripheral non-cycloplegic refractions were evaluated for the naked eye and with both MFCLs. The left eye was always occluded during measurements. Head and eye rotation measurements were performed randomly during the same session 5 min apart from each other.

The peripheral refraction was obtained using an array of light-emitting diodes (LEDs) with a diameter of 5 mm located at 2.5 m along the horizontal visual field at eccentricities between 30° nasally and 30° temporally, in 10° steps. For the eye rotation measurements, the patient was instructed to fixate on the LEDs as previously described [26,33]. For the head rotation measurements, we used a previously reported method [28,26], during which a laser pointer positioned on top of the patient's head was oriented toward the primary gaze position. Room light was kept at low intensity (about 20 cd/m^2, low photopic level) in order to avoid pupil miosis. Under these conditions, the pupil size was large enough to allow measures to be obtained through the elliptical pupil when the eye or head rotated. The patient rotated his or her head, avoiding lateral displacement, until the pointer reached the desired eccentric LED while the eyes remained in the primary gaze position. Individual data were transposed into vector components according to Fourier analysis [34,35]. Five refractive measurements were performed and averaged after transposition into the vector components (M, J0 and J45) for each eccentricity. The refractive data were saved automatically in Microsoft Excel spreadsheets using custom software (DRRE, CEORLab).

2.3. Statistical analysis

The data were analyzed using SPSS for Windows, version 20 (SPSS Inc., New York, USA). The Shapiro–Wilk test was applied to evaluate the normality of the data distribution. Relative peripheral refractive error was obtained by subtracting the central refractive error to the refractive component (M, J0 or J45) at each eccentric location (10, 20, 30° nasal or temporal). The behaviors between the relative peripheral refractive patterns between ocular and head rotation were evaluated for each condition (naked eye, Acuvue Oasys lens for presbyopia, and Biofinity Multifocal D lens). The effect of factors such as measurement location (eccentricities), lens type (naked eye, Acuvue Oasys lens for presbyopia, or Biofinity D lens), and testing method (eye or head rotation) on the mean values of the dependent variables (MJ0, and J45) were evaluated using multivariate analysis of variance (MANOVA). When MANOVA detected the statistically significant effects ($p < 0.05$) of a certain factor, we performed an individual ANOVA for each dependent variable, followed by the Bonferroni post hoc test. A p value lower than 0.05 was considered statistically significant.