Contact Lens & Anterior Eye 38 (2015) 322–326

Contents lists available at ScienceDirect

Contact Lens & Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Assessment of multifocal contact lens over-refraction using an infrared, open-field autorefractor: A preliminary study

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ARTICLE INFO

Article history:
Received 17 October 2014
Received in revised form 20 February 2015
Accepted 28 March 2015

Keywords:
Multifocal contact lens
Simultaneous vision
Over-refraction
Autorefractor
Refractive error

ABSTRACT

Purpose: To evaluate the usefulness of an infrared open-field autorefractor as a predictor of the refractive error when fitting multifocal contact lenses (MCL).
Methods: Objective and subjective measurements of the non-cycloplegic distance refractive error were compared in patients wearing MCL. We used the Grand Seiko WAM-5500 autorefractor for the objective measurements. Three commercially available MCL were tested. Twenty-one eyes of sixteen healthy adults were included in the study. Over-refraction was evaluated in terms of spherical equivalent (SE) and astigmatic vectors (J_0 and J_{45}). The mean difference ± SD of each parameter was calculated. The Kolmogorov–Smirnov test was used to verify the normal distribution. Pearson's correlation, Bland and Altman plot and paired sample *t* test were used to compare the results obtained with both methods.
Results: The mean difference between objective and subjective results of the SE over-refraction was 0.13 ± 0.42D; for astigmatic vectors J_0 and J_{45} were 0.03 ± 0.32D and −0.00 ± 0.17D, respectively. The Kolmogorov–Smirnov test showed a normal distribution for all parameters. The highest Pearson's correlation coefficients were obtained for the SE with values of 0.98 without MCL and 0.97 with MCL. The lowest were obtained for J_{45} with values of 0.65 without MCL and 0.75 with MCL. Significant correlations were obtained for each parameter. The paired sample *t* test failed to show significant differences in analyzed parameters except for J_0 without MCL.
Conclusions: The Grand Seiko WAM-5500 can be used as a screening method of over-refraction in the clinical fitting of MCL.

1. Introduction

Presbyopia is the age-related loss of accommodation that causes blurring at near viewing distances [1]. This condition starts typically around 45 years of age [2]. Presbyopia cannot be prevented and thus eventually affects the whole population. Several methods can assist presbyopes at near viewing distances. Firstly, the use of spectacles: monofocal for near viewing or multifocal designs (including bifocals) for near and far vision. Multifocal intraocular lens (MIOL) designs have been proposed for pseudophakic patients [3] who have lost accommodation after extraction of the crystalline lens. Monovision, bifocal or MCL have been suggested for near viewing distances in presbyopic subjects [4].

Multifocal contact lens (MCL) and MIOL technologies, which are based on diffractive and refractive optical designs, emerged at the end of the 20th Century. In contrast, refractive hydrogel models with aspheric geometry are currently common. MCL are designed to provide several foci in what is known as simultaneous vision. Depending on the viewing distance, the image formed by one of the foci is focused on the retina, while the images of the other foci remain blurred. This allows clear vision for different distances but focused and unfocused images are formed simultaneously on the retina; as a result, glares and halos occur frequently [5].

A contact lens adaptation implies the proper adjustment of parameters such as the radius of curvature, material and diameter [6]. When fitting contact lenses, over-refraction [7], the residual error of refraction of the eye when the patient is wearing contact lenses, is also measured [8]. Based on this result, the refraction of the contact lens is modified to avoid any residual error. In clinical practice an autorefractor is commonly used as a screening method of over-refraction for contact lenses users [9,10]. Indeed, its suitability in monofocal contact lens over-refraction has already been demonstrated [11]. Due to the complex designs of MCL, some inaccuracies in over-refraction measurements obtained with the autorefractor can occur, similar to the inaccuracies found when

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http://dx.doi.org/10.1016/j.clae.2015.03.014
1367-0484/

performing aberrometric measurements in other multifocal systems such as MIOL [12]. However, not all authors report problems when measuring aberrations in MCL [13] and objective accommodative responses have been successfully measured using an autorefractor [14]. Moreover, autorefraction has also been used after cataract surgery in patients with MIOL [15,16]. No comprehensive studies on the evaluation of autorefractors as a screening method for MCL over-refraction have been published. The purpose of this preliminary study was to evaluate the suitability of an infrared open-field autorefractor to obtain an accurate over-refraction evaluation for far viewing distances after fitting MCL in non-cycloplegic adult eyes.

2. Methods

2.1. Subjects

Sixteen healthy young and middle-aged adults (11 men and 5 women) participated in the study. The exclusion criteria for the study were any disease or medication that caused vision problems or contraindicated the use of contact lenses. The age ranged from 26 to 48 years old (31.38 ± 7.34). The study followed the tenets of the Declaration of Helsinki and all patients signed the informed consent after they were explained the nature, procedures and aims of the study.

2.2. Multifocal contact lenses

We used three commercially available soft MCL: Air Optix Multifocal, Acuvue Oasys for presbyopia and Proclear Multifocal. Air Optix® Multifocal (Ciba Vision), used in nine eyes of the study, has a near-center aspheric refractive design [14] composed of Lotrafilcon B with a *Dk* = 110 and a water contents of 33%. Its diameter is 14.2 mm and the base curve 8.6 mm. Acuvue® Oasys™ for presbyopia (Johnson & Johnson), used in six eyes, has also a near-center aspheric refractive design [17] composed of Senafilcon A with a *Dk* = 147 and a water contents of 58%. In this case, the diameter was 14.3 mm and the base curve 8.4 mm. Proclear® Multifocal (Cooper Vision), used in six eyes of the study, has a near-center aspheric refractive design [18] composed of Omafilcon A with PC with a *Dk* = 27 and a water contents of 60%. It has a diameter of 14.4 mm and a base curve of 8.7 mm.

2.3. WAM-5500

The Grand Seiko AutoRef/Keratometer WAM-5500 (Grand Seiko Co. Ltd., Hiroshima, Japan) employed in this study is a binocular open-field autorefractor and keratometer. The basic principle of refractive power measurement consists of capturing the image of a ring target of infrared light after reflection on the retina. The size of the pattern formed at the eye-ground varies in relation to the refractive power. This pattern is then detected by a CCD sensor and analyzed by image processing to calculate the refractive data. The instrument can measure refraction in the range of ±22D sphere and ±10D cylinder in increments of 0.01, 0.12 or 0.25D for power, and 1° for cylinder axis. The vertex distance can be adjusted (to 0, 10, 12, 13.5 or 15 mm); the minimum pupil size for measurement is 2.3 mm [19]. In this study the selected vertex distance was 12 mm. The measurements were performed in illuminance conditions low enough to obtain pupil diameters above 2.3 mm ($\text{Mean}_{\text{PupilDiameter}}$ = 6.27 mm [from 5.6 to 6.8 mm]). The Grand Seiko AutoRef/Keratometer WAM-5500 (Grand Seiko Co. Ltd., Hiroshima, Japan) had been previously validated for all these functions [20].

2.4. Measurement protocol

The measurements were obtained in two different sessions per person; only one eye was fitted with a MCL per session.

The first session started with a medical history, followed by a complete optometric exam without MCL, which included keratometry, distance subjective refraction (Jackson crossed cylinder, maximum plus for best visual acuity) and objective refraction (Grand Seiko AutoRef/Keratometer WAM-5500). The visual acuity (VA) was evaluated with a Bailey & Lovie Chart 5 with the participant at a distance of 6 m (20 ft) [21]; observation through a slit-lamp ruled out any exclusion criteria conditions. Three subjective and objective refraction measurements were performed consecutively.

Once the initial exam was completed, one eye was selected and fitted with a MCL. The dioptric power of the contact lens was chosen randomly, without taking into account the subjective refraction of the patient. This procedure had been used in similar studies that fitted all lenses to ensure good movement and centration on the eye without controlling the power of the lens, thus enabling the evaluation of the autorefractor in a wide range of spherical powers [11]. As a result, in most cases the power of the MCL did not agree with the refraction distance of the patient.

After fitting the MCL, the patient spent 1 h with it to achieve a correct adaptation, checked with the observation of the centration by means of a slit-lamp. Next, three consecutive repetitions of objective over-refraction with the autorefractor and three subjective distance over-refractions were performed to obtain the spherical and astigmatic components of the residual refraction.

In the second session the same procedure was used to fit the MCL on the eye not measured in the previous session.

All measurements were performed by the same optometrist.

2.5. Data analysis

Subjective and objective over-refraction results were entered into a spreadsheet in negative cylindrical form and the mean spherical equivalent (SE; Eq. (1)) and astigmatic refraction were determined. Power Vector analysis [22] was used for astigmatic data at axis 0 (J_0; Eq. (2)) and at axis 45 (J_{45}; Eq. (3)).

$$\text{SE} = \text{sphere} + \left(\frac{\text{cylinder}}{2}\right) \tag{1}$$

$$J_0 = -\left(\frac{\text{cylinder}}{2}\right)\cos(2 * \text{axis}) \tag{2}$$

$$J_{45} = -\left(\frac{\text{cylinder}}{2}\right)\sin(2 * \text{axis}) \tag{3}$$

2.6. Statistical analysis

Statistical analysis was performed with SPSS for Windows [23]. The Kolmogorov–Smirnov test was used to verify the normal distribution of the spherical equivalent (SE), J_0 and J_{45} for objective and subjective over-refraction with and without MCL. The pair of eyes was included as a factor to control for the intereye correlation. In those cases where correlation between eyes was confirmed, one of them was excluded from the study.

Agreement between the objective and subjective over-refraction was evaluated for each measured component with the mean differences ± SD and the 95% confidence limits, as suggested by Bland and Altman [24]. Pearson's correlation coefficient was also calculated to compare both techniques. To evaluate if there was any tendency in the differences to systematically vary over the range of measurements, the Pearson correlation coefficient and its significance were also used in the Bland and Altman plots. Finally, a paired sample *t* test was carried out to analyze if there were significant