Contact Lens & Anterior Eye 34 (2011) 12–16

Contents lists available at ScienceDirect

Contact Lens & Anterior Eye

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

Spherical aberration in relation to visual performance in contact lens wear

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ARTICLE INFO

Keywords:
Spherical aberration
Contact lenses
Aberration control
Daily disposable
Visual acuity
Contrast sensitivity

ABSTRACT

Introduction: The aim of the present study was to evaluate changes in spherical aberration and their effect on visual quality (visual acuity and contrast sensitivity) in both distance and near with different non-custom-made contact lenses.
Methods: A wavefront analyser was used to measure the aberrations in each subject's eyes uncorrected and with the contact lenses: a standard lens and two aspherical contact lenses. High-contrast visual acuity at distance was measured with Test-Chart 2000 (100% contrast) and at near with Sloan ETDRS Near Point chart (100% contrast). Low-contrast visual acuity at distance was measured with Test-Chart 2000 (10% contrast) and contrast measurements at near with Mars letter contrast sensitivity chart.
Results: Mean spherical aberration was positive for all pupil sizes in the uncorrected eye, residual spherical aberration was close to zero with the standard lens for all pupil sizes, whereas the two aspheric contact lenses over-corrected spherical aberration. The changes in aberration were statistically significant ($p < 0.05$) with all lenses. No significant difference could be detected between trial frame correction, spherical and aspherical soft contact lens designs with respect to visual quality. This was the case for both distance and near.
Conclusion: The results are in line with previous studies and indicate that non-custom-made spherical aberration control contact lenses have little effect on visual quality as defined in this study.

1. Introduction

The aim of a contact lens is to provide the lens wearer with as high visual quality as possible both for viewing at distance and near. Defocus is commonly corrected and there are several solutions to compensate for astigmatism giving good or acceptable visual acuity [1,2].

Defocus and astigmatism are lower order aberration (LOA) in terms of the Zernike polynomials. Even if lower order aberrations are the main factor for decreased vision there will also be higher order aberrations (HOA) in the eye [3–7]. Previous studies have shown that spherical aberration will be the higher order aberration affecting image quality the most [8–10]. Spherical aberration within a population will vary markedly with a mean of about 0.1 ± 0.1 μm with a 6 mm pupil [7,11,12]. In an attempt to compensate for spherical aberration of the eye the surfaces of the contact lenses can be made aspheric. Contact lenses with at least one aspherical surface are now available [13]. Theoretically these lenses offer a possibility to increase visual quality, without the lens being custom-made. Previous studies [14,15] have shown that these lenses do reduce the amount of spherical aberration in the unaccommodated eye. Some studies have also claimed that these lenses will increase visual acuity [13,16]. However, in a recent study [14] distance visual acuity and contrast sensitivity were found to be unaffected by these lenses as compared with spherical lenses even though spherical aberration was reduced. Previous studies have shown that the difference in spherical aberration between the lens–eye combinations will be the difference in spherical aberration between the lenses themselves [14,20].

Previous studies on aberration control and contact lenses have focused on evaluation of distance visual quality. However, most contact lens wearers will spend a large portion of their day doing near tasks such as, computer work and reading. When looking at a near object the refractive power of the eye has to be increased and pre-presbyopic subjects will do so by means of accommodation. Accommodation will induce changes in the optics of the crystalline lens and also shift its position. Accommodation will therefore result in changes of the eye's monochromatic aberrations, especially spherical aberration and coma [17–19]. Spherical aberration will change linearly toward negative values with increasing accommodation [18,19]. Correction of spherical aberration of the

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doi:10.1016/j.clae.2010.08.008

Table 1
Parameters and information about the tree soft contact lenses used in this study.

Parameters	Dailies Aqua Comfort Plus	Soflens Daily Disposable	Zeiss Contact Day 1
Material:	Hilafilcon B	Hilafilcon B	Methafilcon A
FDA group:	II	II	IV
Watercontent:	69%	59%	55%
Manufacturing:	Lightstream Tecnologi	Moulding	Moulding
Spherical/aspheric	Spherical	Aspheric	Aspheric
Handling colour:	Visitint	Light blue	Light blue
Diameter (mm):	14.0	14.2	14.2
Base curve (mm):	8.7	8.6	8.6
Center thickness (mm):	0.10 (−3.0 D)	0.09 (−3.0 D)	0.08 (−3.0 D)
Dk/t:	26.0 (−3.0 D)	24.0 (−3.0 D)	24.0 (−3.0 D)
Power range (D):	+0.5 to +6.0 (0.25 D step) −0.5 to −6.0 (0.25 D step) −6.5 to −10.0 (0.5 D step)	+6.5 to −6.0 (0.25 D step) −6.5 to −9.0 (0.5 D step)	+0.5 to +4.0 (0.25 D step) −0.5 to −6.0 (0.25 D step) +4.5 to +6.5 (0.5 D step) −6.5 to −9.0 (0.5 D step)

unaccommodated eye, by means of aspherical contact lens design, may therefore result in an increased amount of negative spherical aberration in the accommodated eye that potentially can reduce near visual quality. The assumption was made that the aberrations of the unaccommodated eye will be constant over the short time period when the lenses were worn.

The aim was to evaluate the notion that aspheric contact lenses reduce aberrations, in the unaccommodated eye, and evaluate visual quality at distance by measuring high- and low-contrast distance visual acuity and near by measuring high-contrast near visual acuity and near contrast sensitivity.

2. Methods

The current study was a single masked randomized and controlled study where visual quality and spherical aberration with three contact lenses were compared. Ethical approval was given by the local ethical committee and the study adhered to the declaration of Helsinki.

2.1. Contact lenses

The contact lenses used in the study were three daily disposable soft lenses: the spherical Dailies Aqua Comfort Plus (Ciba Vision Inc.), and the aspherical Soflens Daily Disposable (Bausch & Lomb) and Zeiss Contact Day 1 (Wöhlk Gmbh). Details of the lenses are given in Table 1.

2.2. Subjects

Healthy subjects were recruited at the School of Optometry, Karolinska Institutet, Stockholm, Sweden. To participate in the study the following criteria had to be met: (1) refractive error between +4.0 and −6.0 SD (to ensure that lenses were available in 0.25 SD) steps of power; (2) astigmatism ≤0.75 DC; (3) age less than 35 (to ensure that the subjects did not need reading addition); (4) no ocular pathology or systemic disorders; (5) not taking any drugs with known effect on visual acuity or accommodation; and (6) contact lens corrected (binocular and monocular) visual acuity of 20/20 (1.0) Snellen units or better.

2.3. High-contrast visual acuity and contrast measurements

Distance visual acuity (6 m) was measured binocularly and monocularly (in logMar units) for right and left eye respectively using Test-Chart 2000. Test-Chart 2000 is a computerised test-chart system developed by Thompson Software widely used in hospitals, clinics and schools in UK [21]. Using the Test-Chart 2000 it is possible to randomly replace letters to avoid learning effects.

Low-contrast (10% contrast) visual acuity for distance was measured binocularly and monocularly using Test-Chart 2000 with randomly replaced letters and visual acuity was noted in logMAR units. A Sloan Two Sided ETDRS Near Point chart was used for high-contrast near visual acuity (100% contrast). The chart used for the worst eye was used for binocular measurements [22]. For all measurements monocular measurements was taken before binocular in order to avoid learning effects, and all notations were made in logMAR units.

The Mars letter contrast sensitivity chart was used to evaluate near contrast sensitivity. This is a hand-held chart, using Sloan letters with 0.04 log unit contrast decrements between each letter. Each letter subtends two degrees when testing at 50 cm [23]. In this study the chart was held at 40 cm by the patient [24]. Three different cards were used, one for the right eye, a second for the left eye and a third for binocular measurements. The test ended when the patient made two consecutive letters reading errors [23]. The scoring sheet used to record the value for near contrast sensitivity was in log contrast sensitivity units. For all measurements at near the illumination level was held constant at 85 cd/m^2 as recommended in the manual for the Mars letter contrast sensitivity test [23].

2.4. Aberrometry

Wavefront aberrations and pupil size were measured with the Zywave™ aberrometer (Bausch & Lomb), which is based on the Hartmann–Shack wavefront technique. The aberrations were measured at distance in the unaided eye and with the three contact

Table 2
Visual acuity and contrast measurements with trial frame and with the three soft contact lenses at distance and near.

Correction	Distance		Near	
	HCVA	LCVA	HCVN	MLCS
Trial frame	−0.12 ± 0.07[a]	0.19 ± 0.08	−0.16 ± 0.08	1.75 ± 0.04
Dailies	−0.14 ± 0.09	0.17 ± 0.08	−0.18 ± 0.06	1.76 ± 0.05
Soflens	−0.12 ± 0.08	0.13 ± 0.08	−0.16 ± 0.05	1.75 ± 0.05
Zeiss	−0.14 ± 0.07	0.16 ± 0.09	−0.19 ± 0.06	1.74 ± 0.06

HCVA, high-contrast visual acuity, log MAR; LCVA, low-contrast visual acuity, log MAR; HCVN, high-contrast visual acuity near, log MAR; MLCS, Mars letter contrast sensitivity, log Contrast Sensitivity (log CS).
[a] Mean ± standard deviation.