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Corneal, Conjunctival effects and blood flow changes related to silicone hydrogel lens wear and their correlations with end of day comfort

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ABSTRACT

Purpose: First, to examine how wearing high and low modulus lenses with two different base curves affected lens fit, and the corneal tissue and bulbar conjunctival vascular tissue (bulbar redness and blood velocity). Secondly, to quantify the associations between these baseline and outcome variables and the third purpose was to correlate these variables with end of day comfort.

Methods: Thirty participants wore higher (PureVision (PV) 8.3, 8.6) and lower (Acuvue Advance (AA) 8.3, 8.7) modulus silicone hydrogel lenses for two weeks on a daily wear basis. Lens fitting characteristics were examined. Corneal epithelial thickness was measured and the cornea and conjunctiva were assessed. RBC velocity was estimated from high magnification bulbar conjunctival images. Subjective comfort/dryness was reported by participants using visual analogue scales.

Results: AA lenses were rated the most comfortable (ANOVA, $p = 0.041$). The least movement was while using the AA 8.3 base curve lens (Tukey $p = 0.028$). Steep AA and PV lenses showed significantly higher conjunctival staining at the 2 week visit (ANOVA, $p = 0.029$). There was a significant decrease in RBC velocity with both steeper AA lenses vs PV lenses (Tukey, $p = 0.001$). Comparing baseline and 2 week visits, there was a significant negative correlation for the PV 8.3 between comfort and superior bulbar staining ($r = -0.53$). For both the PV 8.3 and AA 8.3 reduced RBC velocity was correlated with dryness ($r = 0.61$ and $r = 0.91$, respectively).

Conclusions: Physical differences in contact lenses affect structural and vascular functional aspects of the ocular surface and these may be associated with symptoms of dryness.

1. Introduction

Successful soft contact lens fitting and wear involves the selection of the most appropriate lens materials, dimensions and wearing modality to match the ocular characteristics and patient needs, while giving the best fit and optimized vision [1,2]. Sub-optimal or poorly fitting lenses, however, may alter ocular physiology (structure and/or function) that in combination with symptoms may lead to discontinuation [3–5].

The fitting of a contact lens is typically judged on eye, using both static and dynamic criteria, including lens centration, corneal coverage and lens movement in response to blinking [1]. Observations of physiological responses of the cornea and conjunctiva can be influenced by the contact lens including corneal topography [6,7], lens base curve and peripheral curve radii [8], diameter, edge design, material, modulus, tear exchange [9,10] and dehydration [11–13].

Symptoms, among many sensory variables, are a manifestation of the effect of contact lenses on the anterior surface of the eye. Wearers subjectively report symptoms of dryness, discomfort or irritation [14,15]. For example as many as 50% of hydrogel lens wearers report symptoms of dryness [15–17]. Several strategies have been employed to reduce these symptoms [18,19], but single factor treatments may be clinically ineffective due to the multifactorial etiology of symptoms.

Maintaining optimal oxygen availability and reducing complications in lens wear depends on oxygen transmission through the lens, and via tear exchange. Benjamin et al. [20] reported that the oxygen transmissibility is reduced with lens wear and is reversed when the entire cornea is exposed uniformly. In addition, corneal epithelial thinning has been associated with lowered oxygen transmissibility in long-term lens wearers compared to non-lens wearers [21]. Silicone hydrogel contact lenses transmit more oxygen to the eye compared with conventional hydrogel lenses, are associated with less hypoxia related complications [22–24] and have, therefore, become the preferred lens for clinical fitting compared to lenses with low oxygen permeability [25,26]. Contact lens fit also influences the quality of tear exchange, where lens diameter, base curve or the peripheral lens geometry have been implicated as factors [27,28]. In addition, stiffer more mobile

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lenses have been shown to have a greater tear exchange [10] and reduced comfort in comparison to more elastic materials of lower modulus [27,29,30]. Another potentially influential factor in the physiological responses of the ocular structures is the mechanical effect of the lid. Eyelid pressure has been hypothesized to be a factor in corneal changes on downward gaze angle [31], during eye movements [32] and in a number of visual tasks including reading, and computer work [33].

These effects of lens wear are not limited to the cornea; conjunctival indentation [34,35] and staining [22,35] has also been observed after lens wear. As well, lens wear alters bulbar conjunctival (and perhaps episcleral) and limbal vascularity [36,37] and, in extreme circumstances, can be associated with a vascular response of the cornea [38]. In addition, the hemodynamics of the bulbar conjunctiva might be altered, with a reported reduction in red blood cell (RBC) velocity, during lens wear, compared to non-lens wearing controls [39].

Although sometimes indirect, there is evidence that a number of clinical conditions can be attributed primarily to hypoxia and/or mechanical effects of lens wear, including superior epithelial arcuate lesions, neovascularization, epithelial folds, limbal hyperemia, conjunctival indentation and contact lens papillary conjunctivitis [38,40–42].

The general purpose of this study was to examine if the differences in physical and fitting characteristics between lenses affected ocular surface physiology (structure and function) and sensory (referring to the sensation of dryness and comfort) responses and the associations between these variables after 2 weeks of lens wear. Although not an explicit hypothesis driven part of the experimental design, it is apparent that there is a large number of variables measured over time that might provide particularly useful clinical insight: Are things measured early related to things that occur later, after lens wear?

2. Methods

2.1. Contact lenses and participants

Two silicone hydrogel contact lenses of different modulus were used in the study. The lower modulus lens material was Galyfilcon A (Johnson & Johnson, Acuvue Advance™; abbreviated AA) with a modulus of 0.43 MPa. The higher modulus lens material was Balafilcon A (B + L, PureVision™; abbreviated PV) with a modulus of 1.1 MPa. Each lens material had two base curve options, a steeper base curve (AA 8.3 mm, PV 8.3 mm) and a flatter base curve (AA 8.7 mm, PV 8.6 mm) See Table 1 for chart showing the lens characteristics and images of the edge profile taken with a research grade optical coherence tomography.

Thirty neophyte contact lens wearers were enrolled in the study. Their mean age was 28 ± 1.5yrs and the sample comprised 22 females and 8 males. The participants wore two of the four study lenses for two weeks on a full-time, daily wear basis (6–8 h/day; minimum 5 days per week). Subjects were asked to self-report their wearing time at each study visit. After a washout period of one week they wore the remaining two study lenses for another two weeks. The order of study lens wear and lenses on right or left eyes was randomized. The subjects and the experimenter were masked as an assistant dispensed the lenses, although lenses do have markings which the experimenter avoided. The study was conducted according to the tenets of the Declaration of Helsinki and was approved by the University of Waterloo, Office of Human Research Ethics Committee.

Lens fitting characteristics, bulbar conjunctival and corneal response to lens wear and subjective ratings of comfort were made prior to each lens wear period (Baseline) and after two weeks of lens wear (2 Weeks). All measurements were made using standardized protocols.

2.2. Lens fitting factors

Lens fitting characteristics were assessed with the slit-lamp biomicroscope using a graticule. Lens movement with blink (mm), and lens centration (mm) in the vertical meridian were estimated.

2.3. Bulbar conjunctival and corneal response to lens wear

Bulbar conjunctival hyperemia, staining and indentation were estimated while viewing the ocular surface with a slit-lamp biomicroscope and, where applicable, 2% sodium fluorescein (with a Wratten #12 filter) was used. In all cases, ratings were made on a scale of 0 (negligible) to 100 (severe) for each quadrant (nasal, temporal, superior, and inferior) using the CCLRU/IER visual analogue grading scales [43].

Corneal epithelial thickness was measured using the Visante OCT (Zeiss Meditec, Dublin, CA, USA) and three images were taken. The raw binary image files (*.bin) of the Visante were exported from the instrument to custom software for analysis. The shortest perpendicular distance from anterior to posterior surface of the epithelium was determined by the custom software in order to obtain epithelial thickness by selecting the highest peak of reflection from air to anterior cornea and then from the posterior epithelium to the stroma. Thickness was determined along the vertical meridian at 7 locations, including the apex, each location separated by 1 mm intervals. This procedure was

Table 1
Description and comparison of the contact lenses used in the study. Images (tomograms) of edge profiles taken with a research grade, high resolution optical coherence tomographer.

	Acuvue Advance	PureVision
Manufacturer	J&J Vistakon	Bausch & Lomb
Material	Galyfilcon A	Balafilcon A
FDA classification	I	III
Modulus (MPa)	0.43	1.10
EWC (%)	47%	36%
Dk/t (−3.00D)	86	101
BOZR (mm)	8.40, 8.80	8.30, 8.60
Diameter (mm)	14.00	14.00
Spherical powers (D)	+8.00 to −12.00D	+6.00 to −10.00D
Surface Treatment	Surface Enhancement with Internal Wetting Agent (PVP) throughout the matrix that also coats the lens surface. No permanent plasma treatment	Plasma Oxidation Process (Surface made up of silicate islands that do not completely cover the surface).
Edge Profile at −3.00D (2-D) UHR-OCT tomogram (1000 A-scans × 512 pixels)