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The effect of lens wear on refractive index of conventional hydrogel and silicone-hydrogel contact lenses: A comparative study

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Abstract

Purpose: The purpose of this work was to evaluate the ability of four silicone-hydrogel contact lenses (galyfilcon A, balafilcon A, lotrafilcon A and lotrafilcon B) to retain their equilibrium water content before and after wear, through measurements of refractive index and compare with that of a conventional disposable hydrogel contact lens (etafilcon A).
Methods: The refractive indices of 115 contact lenses were measured using an automated refractometer (CLR 12-70, Index Instruments, Cambridge, U.K.) before and after a schedule of daily wear by 58 patients for 30 days in the case of silicone-hydrogel lenses and 15 days for the conventional contact lenses.
Results: In the silicone-hydrogel contact lenses the changes on the refractive indices were not statistically significant, however after being worn the refractive index of the conventional etalfilcon A hydrogel contact lens increased significantly ($p < 0.001$).
Conclusion: The results presented here show that after being worn the silicone-hydrogel contact lens, show more capacity to retain or to reach their initial equilibrium water content than conventional hydrogel contact lenses. This suggests that the silicone-hydrogel contact lenses are less susceptible to spoilation over time maintaining its biocompatibility and contributing to the clinical success of lens performance.

Keywords: Refractive index; Automated refractometer CLR 12-70; Silicone-hydrogel contact lenses; Conventional hydrogel contact lens; Equilibrium water content

1. Introduction

Refractive index is a physical parameter that reflects the polymers composition of the contact lenses and also their equilibrium water content (EWC), and so it is an important parameter for the optical and physiological perspective. The EWC represents the ability of the hydrogel materials to bind water and it is an important property for clinical behaviour of the contact lenses.

Water plays a key role in the functionality of hydrogel contact lens materials because it has an important effect on the ion and gaseous permeability [1], mechanical and surface properties [2], and also on the biocompatibility of the contact lenses. It has been shown that an increase in refractive index compared to the ‘‘true’’ refractive index is a surrogate outcome for lens dehydration [3]. Lens dehydration can cause changes in contact lenses parameters leading to a decrease in their clinical performance [4–6]. It has also been shown that environmental conditions can significantly affect contact lenses dehydration [4,7–9]. Many studies link contact lens wear discontinuation results to dehydration of the ocular surface, which is one of the main factors restricting the growth of the contact lenses market [10,11].

Although, the evidence is inconclusive that the loss of lens water content occurring during contact lens wear is responsible for dryness symptoms [12–14], the lens materials capacity to maintain its EWC during wear may be an important factor to consider for the clinical success of contact lenses. In fact, clinical and experimental

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observations made in conventional hydrogel contact lenses with higher water content show that these lenses tend to dehydrate on the eye faster and by a greater amount [12,13,15] and some lenses exhibit an irreversible loss of water over time [12].

Patients using frequent replacement lenses complain less of dryness than wearers of other lens types [16,17]. This may be due to increased wettability [18], reduction deposition [19] or reduced dehydration [20]. In addition, wearers of silicone-hydrogel contact lenses are also less aware of lens-induced dryness, particularly at the end of the day [20].

The water content of conventional hydrogel contact lenses is usually above 38%, which contributes to the softness and comfort of these lenses. However, the oxygen permeability is limited by the water phase restricting their wearing schedule. The silicone-hydrogel contact lenses were developed in order to increase the oxygen transmissibility to the cornea, and thus preventing complications due to corneal anoxia observed with the use of conventional hydrogel contact lenses.

Silicone-hydrogel contact lenses are slightly stiffer and have relatively lower water content than the conventional hydrogel materials. The silicone components combined with conventional hydrogel monomers in contact lens materials, increases oxygen permeability but decreases its hydrophilicity [21] making lens surface more hydrophobic and so more prone to deposits adhesion. This has been already established in *vitro* studies [22–25].

A surface treatment of silicone-hydrogel contact lenses is needed to make them hydrophilic and tolerable on the eye and is an important factor for the clinical performance of these contact lenses. Significant differences exist between the silicone-hydrogels materials [2,26]. Balafilcon A, lotrafilcon A and lotrafilcon B are treated using gas plasma techniques, but balafilcon A undergoes plasma oxidation which transforms the silicone components into glassy islands on the surface. Lotrafilcon lenses are treated with hydrocarbon plasma that reacts with air to create continuous hydrophilic surfaces [2,26]. On the other hand, galyfilcon A has no surface treatment but incorporates an internal wetting agent that apparently leaches to the lens surface.

Refractive index and EWC are closely linked in conventional soft hydrophilic materials [27,28]. In a previous study was also reported a similar, but independent relationship to that of the conventional hydrogels, between refractive index and EWC for the four silicone-hydrogel contact lenses used in this work [29].

Recently, the automated refractometer CLR 12-70 designed to measure the refractive index of hydrogel lenses has become available. Nichols and Berntsen used this instrument and found it easy to use and it is a reliable and valid technique to determine the refractive index of soft contact lenses [3]. These authors found good reliability within and between operators in the measurements of the refractive index using this refractometer and also demonstrated that this instrument had excellent within-operator reliability. We consider these factors as an advantage of measuring hydrogel refractive index rather than measuring water content directly.

As the refractive index reflects changes in the EWC of the contact lens materials, changes on refractive index, allows the evaluation of the ability of the contact lenses to reach or to maintain their EWC after being worn.

The purpose of this work was to evaluate the ability of four silicone-hydrogel contact lenses (galyfilcon A, balafilcon A, lotrafilcon A and lotrafilcon B) to reach or retain their EWC, through measurements of refractive index, and compare with those occurred on a conventional disposable hydrogel contact lens (etafilcon A).

2. Material and methods

A total of 115 commercial lenses were measured: 22 Acuvue® Advance™, 20 Purevision™, 24 Focus® Night&Day™, 19 O_2Optix™, and 30 Acuvue®. The properties of the contact lens used in this study are detailed in Table 1.

Table 1
Conventional and silicone-hydrogel contact lenses used in this study

Brand	Acuvue® Advance™	Purevision™	Focus® Night&Day™	O_2Optix™	Acuvue®
Manufacturer	Johnson & Johnson	Bausch & Lomb	CIBA Vision	CIBA Vision	Johnson & Johnson
USAN	Galyfilcon A	Balafilcon A	Lotrafilcon A	Lotrafilcon B	Etafilcon A
FDA group	I	III	I	I	IV
Water content (%)	47	36	24	33	58
Surface treatment	No surface treatment	Gas plasma oxidation	Plasma coating	Plasma coating	No surface treatment
RI	1.4055[a]	1.426[a]	1.43[a]	1.42[a]	1.4055[a]
Principal monomers	mPDMS + DMA + EGDMA + HEMA + siloxane macromer + PVP + visibility tint + UV blocker	NVP + TPVC + NCVE + PBVC	DMA + TRIS + siloxane macromer	DMA + TRIS + siloxane macromer + visibility tint	HEMA + MA

USAN, United States Adopted Names.

[a] Obtained from Food and Drug Administration, DMA *N*, *N*-dimethylacrylamide; PDMS, polydimethylsiloxane; EGDMA, ethylene glycol dimethacrylate; HEMA, poly-2-hydroxiethylmethacrylate; MA, methacrylic acid; NVP, *N*-vinyl pyrrolidone; TPVC, tris-(trimethylsiloxysilyl) propylvinyl carbamate; NCVE, *N*-carboxyvinyl ester; PBVC, poly[dimethysiloxy] di(silylbutanol) bis[vinyl carbamate].