Dehydration of Hydrogel Lenses during Overnight Wear

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ABSTRACT

We studied the extent of dehydration of hydrogel lenses during overnight wear. Seven subjects used a hand refractometer to measure the water content of five different lenses (Hydran zero-6 (nominal water content 38.6%), −0.50 D, Snoflex 50 (52.5%), −0.50 and +15.00 D, and Hydran Z-67 (67.5%), −0.50 and +15.00 D) before and after 7 h of both open- and closed-eye wear. No statistically significant difference was observed in dehydration between open and closed eye lens wear. Thick and thin lenses made of the same material were found to dehydrate to an equal extent. Contrary to expectations, the medium water content Snoflex 50 lenses displayed a greater absolute decrease in water content than the higher water content Hydran Z-67 lenses (p < 0.01). Factors that may influence the extent of dehydration under open- and closed-eye wearing conditions, and the clinical implications of these results, are discussed.

Key Words: hydrogel contact lens, hand refractometer, dehydration, extended wear, closed eye

Considerable interest has been evoked by reports of in vivo dehydration of hydrogel contact lenses. It has been established that significant differences exist in the extent and time course of dehydration between lenses of different materials and thicknesses.1,2 Contact lens practitioners need to understand these dehydration characteristics for a number of reasons: lens parameters such as curvature and diameter will vary with dehydration, particularly in higher water content lenses;3,4 lens dehydration will necessarily result in a decrease in oxygen transmissibility, consequently reducing corneal oxygen availability;5 and the development of corneal erosions during the wear of thin, high water content lenses has been linked to loss of water from the lenses soon after insertion.6

In view of the present popularity of contact lenses for extended wear, it is pertinent to investigate the stability of hydrogel lens hydration under closed-eye conditions. Andrasko7 reported that a Bausch & Lomb Soflens (38.6% water content) displayed a relative loss of water content of 11.4% after 30 min of closed-eye wear and 13.2% after the same period of open-eye wear by one subject. Based on these limited data, he concluded that "more dehydration occurs when the eyes are open than when they are closed." The aim of the present study was to determine whether dehydration of hydrogel lenses worn overnight (eyes closed) is different from dehydration during daily wear (eyes open) for a variety of lens types.

The major experimental difficulty in determining the extent of lens dehydration during sleep is obtaining measurements from the lenses upon awakening. Two laboratory-based techniques have been used to measure hydrogel lens water content—gravimetry2,8 and refractometry.4,10 Both of these techniques require the use of equipment (precision balance, vacuum oven, Abbe refractometer) that is not easily transportable for overnight studies. The recent availability of a simple, portable hand refractometer11 has made it possible to conduct experiments outside of the laboratory. In this study, experimental subjects used a hand refractometer to measure the dehydration of hydrogel lenses of different water contents and thicknesses under normal daytime and overnight wearing conditions.

METHODS

Seven healthy subjects (six male, one female, age 28 ± 4 years) with no evidence ofocular
pathology volunteered to enter this study. The nature of the procedures was explained fully and informed consent was obtained. These subjects were experienced participants in contact lens experiments and thus were accustomed to lens insertion and removal.

Five contact lenses were used in this study, comprising three lens types: Hydron zero-6 (nominal water content 38.6%), Snoflex 50 (62.5%), and Hydron Z-67 (67.5%). The Hydron zero-6 lens was obtained in a power of -0.50 D and the Snoflex 50 and Hydron Z-67 lenses were each obtained in powers of -0.50 and +15.00 D. A +15.00 D Hydron zero-6 lens was not used for the study because of the possibility of adverse ocular effects during closed-eye wear.

Lens water content was monitored with Atago hand refractometers (Atago Co. Ltd, 32-10 Honcho, Ibashi-ku, Tokyo 173, Japan). Brennan1 has described this instrument in detail and has demonstrated its validity for measuring the water content of hydrogel lenses. The principle of this technique is that the refractive index of a hydrogel lens is determined by its water content. The hand refractometer is a hand-held optical device that is operated by placing the lens against an exposed prism face. The refractive index difference between the hydrogel lens and prism determines the angle of refraction of the limiting light ray within the instrument, causing part of the field to appear brighter as viewed through the eyepiece. The division between bright and dark fields in relation to an internal scale indicates the water content of the lens.

Extensive instructions were given in the use of the hand refractometer and proficiency was measured by having each subject measure a number of lenses of various water contents; one of us verified that this procedure was carried out correctly and that each measurement was recorded accurately. The hand refractometer is a simple instrument that gives reproducible readings of the water content of a hydrogel lens to an accuracy of ±0.5%. It should be noted that the subjects were naive with respect to the likely outcome of the study, thus avoiding bias due to expectation of the results. A record sheet and written instructions in the use of the refractometer were provided.

Before each wearing trial, the refractometer was calibrated according to the manufacturer's guidelines. For day wear trials, the subjects were instructed to wear the lens on days when they would be performing no unusual duties. At least 1 h after awakening, the subject removed the lens from its vial, shook the lens to remove excess surface moisture, measured the water content on a hand refractometer (Atago N2 or N3, depending on lens type), recorded the information, and inserted the lens. At the end of exactly 7 h of wear the subject removed the lens from the eye, and measured and recorded the water content immediately.

For overnight wearing trials, the subjects followed the same pretreatment procedure as for the day wear trials, and then inserted the lens before going to sleep. Immediately on eye opening, after exactly 7 h of sleep, the subject removed the lens, then measured and recorded the water content. All refractometry measurements were made by placing the anterior lens surface in apposition with the prism face. Previous studies have indicated that differences between the front and back surfaces of hydrogel lenses in vivo will introduce minimal error in the estimation of lens water content.6,7

It should be noted that a single measurement of water content was obtained before and after lens wear for both daytime and overnight wearing trials. This was necessary because hydrogel lenses continue to dehydrate after removal from saline storage or the eye6 repeated measurements would therefore have resulted in an underestimation of the true in vivo water content.

The order of the 10 wearing trials (5 daytime and 5 overnight) was randomized and all trials were separated by at least 24 h. The subjects were not informed of the type of lens worn, and the lenses were worn in the same eye (chosen by the subject; usually the nondominant eye) for all experiments.

Between wearing trials, the lenses were cleaned with Polyclean (Alcon Laboratories, Australia), disinfected and neutralized with Softone hydrogen peroxide disinfecting system (Barneer Hind, Australia), and rinsed with sorbic acid-preserved saline (Alcon Laboratories, Australia).

RESULTS

The definitions of dehydration used in this paper conform to those recommended by Brennan et al.3 Measured water contents of all lenses before and after wear during open- and closed-eye conditions are shown in Table 1. The raw data were entered into the University of Melbourne QVAX computer system and the variance was analyzed using the GLM statistical package.4 The sources of variance investigated were lens type L, condition of wear C (open- and closed-eye wear), time of measurement T (before
Table 1. Water contents of hydrogel lenses before and after open- and closed-eye wear.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Hydron zero-lter 0.50 D</th>
<th>Snelax 50° 0.50 D</th>
<th>Snelax 50° 15.00 D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open</td>
<td>Closed</td>
<td>Open</td>
</tr>
<tr>
<td>1</td>
<td>Before</td>
<td>41.0*</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>40.0</td>
<td>39.9</td>
</tr>
<tr>
<td>2</td>
<td>Before</td>
<td>40.5</td>
<td>40.2</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>38.5</td>
<td>37.8</td>
</tr>
<tr>
<td>3</td>
<td>Before</td>
<td>39.2</td>
<td>39.2</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>38.9</td>
<td>38.6</td>
</tr>
<tr>
<td>4</td>
<td>Before</td>
<td>40.7</td>
<td>41.0</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>41.0</td>
<td>40.0</td>
</tr>
<tr>
<td>5</td>
<td>Before</td>
<td>41.0</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>41.0</td>
<td>40.5</td>
</tr>
<tr>
<td>6</td>
<td>Before</td>
<td>37.0</td>
<td>37.0</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>37.0</td>
<td>37.5</td>
</tr>
</tbody>
</table>

Mean ± SD Before 40.5 ± 0.6 40.3 ± 0.9 53.8 ± 3.0 53.9 ± 2.1 53.8 ± 2.1 54.0 ± 1.5
Mean ± SD After 39.0 ± 1.4 38.5 ± 1.2 46.5 ± 3.3 46.2 ± 3.2 47.1 ± 1.6 46.6 ± 1.9

* Poly (2-hydroxyethyl methacrylate).
* Glycerol monoethyl methacrylate.
* Terpolymer of vinyl pyrrolidone.
* Each datum point represents a single measurement of water content.

and after lens wear), and interactions between these factors. Intersubject variation S (and interactions) provided the error terms on which to test the major factors for significant effect.

The results of the analysis of variance are summarized in Table 2. As expected, the single order factors L and T provided significant sources of variance, indicating differences in water content between lens types and differences in water content before and after wear. However, these factors should not be considered independently because of the significance of the higher-order interaction LT (analysis of variance, F = 40.6, p < 0.01), which means that there are significant differences in the extent of dehydration between lens types. Tukey's test revealed no significant difference between the amount of dehydration occurring with the -0.50 and +15.00 D lens for both the Snelax 50 and Hydron Z-67 lens types. The main interaction of interest to this study (T.C) did not show significance, meaning that no difference between open- and closed-eye dehydration could be demonstrated.

The absolute decrease in water content for each of the lenses under open- and closed-eye conditions is graphed in Fig. 1. A decrease in water content is expressed in this figure as a positive quantity for convenience. This figure illustrates the similarity between open- and closed-eye dehydration for all the lenses tested, and demonstrates the differences in the amount of dehydration between lens types. The average decrease in water content of the Snelax 50 lenses (grouped data of both lenses, open- and closed-eye) was significantly greater than that of the Hydron Z-67 lenses (Student's t-test, t = 4.52, N = 28, p < 0.001).

**DISCUSSION**

This study investigated differences in the dehydration characteristics of a variety of hydrogel lenses under open- and closed-eye conditions. Whilst the extent of dehydration during open-eye wear observed here is of similar magnitude to previous reports, several differences are apparent.

The absolute decrease in lens water content was not predictable on the basis of the initial water content of the lens, in contrast to previous reports. The Snelax 50 lens displayed a greater decrease in water content than the Hydron Z-67, which had a higher initial water content. The extent to which a hydrogel lens dehydrates in vivo may depend upon the way in which the water is associated with the polymer—specifically, the relative proportion of water that is bound to the kerogel as opposed to that which is free to move. Further consideration of the ionic nature of a lens polymer may give an indication of the dehydration characteristics of that material.

Our results also indicate that thickness does
which may contribute to a decrease in the lens water content. Conversely, evaporation can be assumed to be virtually eliminated and the tears become relatively hypotonic, which would tend to minimize the amount of dehydration relative to open-eye conditions.

The contribution of each of these competing environmental influences is variable and difficult to predict. Hawding claims that the temperature is the predominant factor in hydrogel lens dehydration, which would be particularly relevant to the increase in temperature from the vial (say, 20°C) to the eye (35°C). However, caution must be exercised when interpreting Hawding's results inasmuch as he found much smaller levels of lens dehydration than have been reported elsewhere. Fatt and Chaston found an absolute decrease in water content of only 2.5% in a 20% water content hydrogel lens in vitro when temperature was increased from 21°C to 35°C. Because previous studies have found greater decreases in water content in vitro, it appears that other factors contribute to dehydration on the eye. Indeed, Kohler and Flanagan have provided evidence that evaporation is responsible for a significant proportion of dehydration in vivo. A relatively minor influence on lens water content is expected for the differences in pH and osmolarity known to exist between the open and closed eye.

In considering the above factors, several reasons may be offered to explain the similarity between open- and closed-eye lens dehydration. First, the principal competing influences of increased temperature and decreased evaporation under the closed lid may counterbalance. Second, there was considerable intersubject variability in the extent of dehydration for the various lens types. The contributions of (1) evaporation in the open eye and (2) increased temperature in the closed eye may be masked by this variability.

A significant decrease in lens water content overnight is of particular relevance to the extended wear of hydrogel lenses. Because the extent of dehydration under the closed eye parallels that under open-eye conditions, changes in lens parameters such as size, shape, and oxygen transmissibility will be similar in both cases.

This information will be of value to practitioners in evaluating the physiological effects of hydrogel lenses upon the anterior ocular structures during various phases of extended wear. Furthermore, a knowledge of dehydration characteristics of various hydrogel lenses may be useful in lens selection. For example, inconsistent lens fitting characteristics, either reported by the patient or observed by the practitioner,

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