Effects of Silicone Hydrogel Contact Lens Wear on Ocular Surface Sensitivity to Tactile, Pneumatic Mechanical, and Chemical Stimulation

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PURPOSE. To determine the effects of silicone hydrogel lens wear and lens–solution interactions on ocular surface sensitivity.

METHODS. Forty-eight adapted lens wearers completed the study, which comprised two phases. Phase 1 included habitual lens wear, no lens wear (7 ± 3 days), and balaficon A lenses (PV; PureVision; Bausch & Lomb, Rochester, NY) with a hydrogen peroxide-based regimen for 2 weeks; phase 2 included wear of PV with the use of a multipurpose solution containing either polyhexamethylene-biguanide (PHMB) or Polyquad/Aldox (Alcon Laboratories, Fort Worth, TX) preservative, each for 1 week, with a 2-week washout period between solutions. Tactile and pneumatic (mechanical and chemical) stimuli were delivered, and thresholds were determined by Cochet-Bonnet (Luneau Ophthalmologie, Chartres, France) and Belmonte (Co-operative Research Centre for Eye Research and Technology, Sydney, NSW, Australia) pneumatic esthesiometers, respectively. Corneal and conjunctival thresholds and staining scores were assessed at baseline, after 2 and 8 hours of lens wear on day 1 and at the end of each wearing cycle (2 hours).

RESULTS. In phase 1, compared to the no-lens baseline, corneal tactile thresholds increased at the 1-day, 8-hour and the 2-week visits (P < 0.05), whereas conjunctival mechanical thresholds decreased at the 1-day, 2-hour and the 2-week visits (P < 0.05). In phase 2, the chemical thresholds were lower with PHMB-preserved solution compared with the Polyquad/Aldox system at the 1-day, 2-hour and the 1-week visits (P < 0.05). Staining scores correlated inversely with conjunctival chemical thresholds (all P < 0.05).

CONCLUSIONS. Ocular surface sensitivity changed in adapted lens wearers, when lenses were refit after a no-lens interval and during lens wear with different care regimens. The corneal staining that was observed with certain lens–solution combinations was accompanied by sensory alteration of the ocular surface—that is, higher levels of staining correlated with increased conjunctival chemical sensitivity. (ClinicalTrials.gov number, NCT00455455.) (Invest Ophthalmol Vis Sci. 2010;51:6111–6117) DOI:10.1167/iovs.09-4807

Highly oxygen-permeable silicone hydrogel (SH) lenses offer certain advantages over traditional hydrogel lenses by eliminating lens-induced hypoxia and producing less detrimental effects on corneal homeostasis.3 Despite these ocular health benefits, SH lens wear is generally similar to hydrogel lens wear in its mechanical interaction with the ocular surface and the effects on the structure and physiology of the tear film.2

The contact lens interacts with the cornea and conjunctiva, each being innervated by sensory nerve endings3 that are functionally heterogeneous5: Mechanonociceptors respond to mechanical stimuli only, cold receptors signal downward temperature changes in the non-noxious range, and polymodal nociceptors respond to mechanical, chemical, and thermal stimuli.4 The cornea and conjunctiva provide sensory input to the functional unit comprising the ocular surface (cornea, conjunctiva, and meibomian glands), the lacrimal glands, and the sensory and motor nerves that connect them.5 Through a complex network, the afferent and efferent nerves link the components of the integrated unit into a homeostatic loop, with the primary function of protecting and maintaining the health of the ocular surface and the tear film.6 In addition, corneal sensory nerves exert various trophic effects on the cornea, which may play a role in the modulation of wound healing after corneal injuries.7

The measurement of ocular surface sensitivity is one way to assess the functioning of the sensory nerves and has been a useful clinical indicator of corneal health, in contact lens wear and corneal disease and during the healing process after various corneal injuries and refractive surgery.9–10 In the past, sensitivity has been measured mainly by Cochet-Bonnet-type esthesiometers (Luneau Ophthalmologie, Chartres, France),11,12 in which hair or nylon filaments of variable diameters and lengths are used to deliver tactile stimuli to the ocular surface. The more recently developed pneumatic esthesiometers13–15 deliver controlled air pulses at various temperature and air-CO2 mixtures to the ocular surface and allow measurements of ocular surface sensitivity over a range of thermal, mechanical, and chemical stimuli.

Reduced corneal sensitivity has been reported in contact lens wear.16–21 The reduction in sensitivity seems to be eliminated after the cessation of lens wear.7,18 Metabolic impairment (i.e., hypoxia) has been considered to be the principal cause of reduced sensory nerve function of traditional low-oxygen-permeability (Dk) hydrogel lenses.21,25 Other factors contributing to this sensitivity loss include sensory adaptation,26–27 and acidosis-suppressed corneal nerve function.8 Most published reports have been based on wearing earlier generation lenses of low-Dk materials, and the sensitivity measurements have been limited to tactile stimulation. It is largely unknown whether SH lens wear affects ocular surface sensi-
tivity differently, particularly when lens-induced hypoxia has been reduced or eliminated. Also, there have been no reports on how tactile, mechanical, and chemical sensitivity changes with SH lens wear over time. Moreover, perhaps due to the unique nature of SH lens materials, there is accumulating evidence that the interaction between certain SH lenses and preserved multipurpose solutions (MPSs) affects the ocular surface, manifesting in corneal fluorescent staining. It is unclear whether the interaction between the lens material and care regimens would have an impact on ocular surface sensitivity, although one study with a small sample has intimated that this may be the case.

The present study investigated the effects of SH lens wear and lens–solution interactions on ocular surface sensitivity. We used different stimuli delivered by Cochet-Bonnet and Belmonte (Cooperative Research Centre for Eye Research and Technology, Sydney, NSW, Australia) esthesiometers and measured corneal and conjunctival thresholds in a group of adapted contact lens wearers, before and during a short period of cessation of lens wear and after refitting with SH lenses disinfected with a variety of care regimens.

METHODS AND MATERIALS

This study was conducted in accordance with the guidelines of the Declaration of Helsinki and received clearance from the University of Waterloo, Office of Research Ethics (Waterloo, Ontario, Canada). Informed consent was obtained from each subject.

Subjects

Sample size calculations to detect significant differences were derived from unpublished data; the sample size necessary to achieve a power of 0.80 with an effect size of 0.4 at a 5% significance level was 50. The 50 subjects, consisting of 35 women and 15 men (mean age 25.2 ± 7.4 years; range 18–45), were adapted contact lens wearers and were asymptomatic during at least 8 hours of lens wear. Each subject had no history of eye surgery or systemic or ocular disease and was not using any systemic or topical medication that would affect ocular health. Two subjects did not complete the study: one due to a burning sensation during lens insertion and the other one for personal reasons. Before entering the study, 27 of 48 subjects who completed the study were wearing conventional hydrogel lenses, and 21 were SH lens wearers. The median length of contact lens wear was 7 years (10th, 90th percentiles: 2, 15 years).

Study Lens and Care Regimens

Balafilcon A SH lenses (PureVision; Bausch & Lomb, Rochester, NY) and three lens care regimens were used in the study. A hydrogen peroxide-based regimen (Aosept; CIBA Vision, Duluth, GA) was used in phase I and in a washout period in phase II, to eliminate potential confounding effects of surfactants and preservatives. Two multipurpose solutions (MPSs), a polyhexamethylene biguanide (PHMB)-based product (ReNu MultiPlus; Bausch & Lomb) and a solution preserved with Polysquid (polysquaternium-1) and Aldox (myristamidopropyl dimethylamine; Opti-Free Replenish; Alcon Laboratories, Fort Worth, TX), were used in phase II. The subjects wore balafilcon A lenses throughout the study, fitted according to the manufacturer’s guidelines on a daily wear basis. Each subject received a new pair of lenses on commencing each lens care regimen period. The lenses were cleaned and disinfected after each wearing period (i.e., after each day of lens wear), using the lens care regimen assigned to each particular phase. The subjects were not permitted to use rewetting drops while wearing the study lenses.

Study Protocol

The study had a randomized, single (experimenter)-masked, bilateral crossover design, as illustrated in Figure 1. It consisted of two phases: phase I included habitual lens wear, no lens wear, and use of PureVision (PV) lenses with Aosept for 2 weeks. Phase II included PV with the two MPS care regimens (each for 1 week), with a 2-week washout period during which PV lenses with Aosept were used. The order of the MPSs used in phase II was randomly assigned, and the investigator was masked with respect to the solution that each subject was using.

The subjects were initially seen with their own lenses after 2 hours of wear to establish their habitual baselines, followed by determining the power and fit of the study lenses. They were then asked to cease lens wear for minimum of 4 days (7 ± 3 days). At the end of this washout period and 4 to 6 hours after awakening (to minimize diurnal effects), a second no-lens baseline was measured. Study lenses were then dispensed to the subjects, and measurements were taken on the following day at either 2 or 8 hours after insertion, depending on the randomization order. The subjects continued to wear the lenses and using the specified care regimen for 2 weeks, after which they returned for measurements after 2 hours of lens wear. This completed phase I and started the first baseline for phase II.

The subjects were then randomly assigned to one of the two care solution groups. The day-1 measurements for phase II were taken on the next 2 days after assignment of the care solution, in the same manner as for day 1 in phase I. The subjects wore the lenses for 1 week and returned for a week-1 assessment after 2 hours of lens wear. After this, the subjects returned to the Aosept care solution for a 2-week washout. When the subjects returned after 2 weeks, a second baseline measurement was taken after 2 hours of lens wear, and the subjects were assigned to the alternative care solution. The series of measurements was then repeated with this second care solution.

After slit lamp biomicroscopy to examine the lens and ocular surface, corneal and conjunctival thresholds to tactile, pneumatic mechanical, and chemical stimulation were measured in one eye at each visit (Fig. 1). The test eye was determined randomly, and the same eye was used throughout the study.

Primary Outcome Measures

Tactile Stimulation Thresholds. Tactile thresholds were measured with a Cochet-Bonnet esthesiometer. A nylon thread (0.12-mm diameter) was used to deliver tactile stimulation to the cornea and conjunctiva. The length of the thread was decreased in 5-mm steps until the participant reported feeling it, and the length of the stimulus detected was converted into pressure according to the table provided by the manufacturer.

Pneumatic Mechanical and Chemical Stimulation Thresholds. A computerized Belmonte pneumatic esthesiometer that has been described in detail elsewhere was used to measure mechanical and chemical thresholds, with an ascending method of limits. The tip of the esthesiometer was set 5 mm from the corneal and conjunctival surface and monitored with a calibrated video camera. The mechanical stimuli consisted of a series of air pulses with flow rates varying from 0 to 200 mL/min. Chemical stimulation was induced by increasing the concentration of CO2 in the air (with the stimulus flow rate fixed at half of the estimated mechanical threshold). For both mechanical and chemical threshold measures, the stimulus temperature was at 50°C, which was approximately 35°C at the ocular surface. The stimulus duration was 2 seconds, with 20- and 45-second intervals between the subject’s response and the next stimulus for mechanical and chemical measures, respectively.

Tactile, pneumatic mechanical, and chemical thresholds were estimated on the temporal midperipheral cornea (~3 mm from the apex) and temporal conjunctiva (~5 mm from the limbus). A training session was conducted on the temporal midperipheral cornea of the contralateral eye before measurement. The subjects were instructed to view fixation targets at about 3 m and to blink freely between stimuli. They could interrupt the trials if necessary. Corneal and conjunctival detection thresholds were the average of...
three intensities at stimulus detection for each modality of stimulation. The measures were performed in the following order: pneumatic mechanical, chemical, and tactile thresholds.

Secondary Outcome Measure

Five regions of the cornea (central, inferior, temporal, superior, and nasal), as depicted in Figure 2, were evaluated for staining 2 to 3 minutes after sodium fluorescein instillation (a fluorescein strip [Ful-Glo; Akorn Pharmaceuticals, Lake Forest, IL] wetted by single-dose saline Minims [S & N Pharmaceuticals, Pinetown, South Africa]), using cobalt light (no. 12 Wratten filter; Eastman Kodak, Rochester, NY). A percent staining area was calculated based on the average staining area (extent) observed across all five regions. Conjunctival staining was measured using lissamine green (Rose Stone Enterprises, Rancho Cucamonga, CA), with white light and a red filter (25A; Hoya Corp. USA, Santa Clara, CA) and graded based on the severity of each region (inferior, temporal, superior, and nasal) on a scale consisting of 0 (none), 1 (trace), 2 (mild), 3 (moderate), and 4 (severe).

Statistical Analyses

Repeated measures analyses of variance (ANOVA) and post hoc Tukey HSD tests were performed on the thresholds and corneal staining data (Statistica, ver. 8.0; StatSoft Inc., Tulsa, OK). $P \leq 0.05$ was considered to be statistically significant. For repeated-measures ANOVAs, to minimize the effects of violating assumptions about data sphericity, we report Huynh-Feldt-corrected $P$ values. The difference in thresholds in phase I was compared between visits. For phase II data, the main effects of MPS and visit and their interaction were examined. In addition, Friedman ANOVA and post hoc Wilcoxon with Bonferroni correction were used to test the differences in conjunctival staining between MPSs and visits. Pearson correlations were performed between thresholds and corneal staining scores.

**Figure 1.** Flowchart of study design and visits. *The 2- and 8-hour measurements were taken on consecutive days, to ensure that the lenses would be worn for 8 consecutive hours before the 8-hour measurement. To eliminate the time effect introduced by the order of the measurement sessions, they were conducted in a random order at 2 and 8 hours after lens insertion.*

**Figure 2.** Diagram of the five corneal regions divided for grading corneal staining. C, central; T, temporal; N, nasal; S, superior; I, inferior.
TABLE 1. Corneal and Conjunctival Tactile, Pneumatic Mechanical, and Chemical Thresholds in Phase I

<table>
<thead>
<tr>
<th>Lens Wear</th>
<th>Tactile (mm/g/s)</th>
<th>Pneumatic Mechanical (Air Flow mL/min)</th>
<th>Chemical (%CO₂ Added)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cornea</td>
<td>Conjunctiva</td>
<td>Cornea</td>
</tr>
<tr>
<td>Habitual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV lens and Aosept solution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1, 2 h</td>
<td>32.4 ± 15.9</td>
<td>122.5 ± 33.5</td>
<td>47.9 ± 23.5</td>
</tr>
<tr>
<td>Day 1, 8 h</td>
<td>35.1 ± 20.5</td>
<td>126.0 ± 42.0</td>
<td>47.4 ± 23.8</td>
</tr>
<tr>
<td>Week 2, 2 h</td>
<td>34.5 ± 19.0</td>
<td>121.4 ± 39.6</td>
<td>49.6 ± 24.6</td>
</tr>
</tbody>
</table>

Data are expressed as the mean ± SD.

Although all analyses of esthesiometry data were performed on the thresholds, because sensitivity is the reciprocal of the threshold and the most commonly used term, this term is used in discussing these outcomes.

RESULTS

Effects of SH Lens Wear on Corneal and Conjunctival Sensitivity

Corneal and conjunctival thresholds for tactile, pneumatic mechanical, and chemical stimulation for phase I are presented in Table 1.

There was a significant difference in corneal tactile threshold between visits (P = 0.003; ANOVA). At the 8-hour examination on day 1 and the 2-week visit after the study lens was dispensed, the tactile threshold was higher than that at the end of the no-lens-wear period (Tukey HSD, P = 0.003 and 0.012 for the 1-day, 8-hour and the 2-week visits, respectively). There was no significant change in conjunctival tactile thresholds between visits (P > 0.05, ANOVA).

For pneumatic mechanical thresholds, there were significant differences in both corneal and conjunctival thresholds between visits (P = 0.027 and 0.008 for cornea and conjunctiva, respectively, ANOVA). Corneal thresholds at the 2- and 8-hour examinations on day 1 were lower than those with habitual lens wear (Tukey HSD, P = 0.036 and 0.022 for the 2- and 8-hour examinations, respectively). The conjunctival threshold at the end of the no-lens-wear period was higher than measurements taken after 2 hours of PV lens wear at the 1-day and 2-week visits (Tukey HSD, P = 0.003 and 0.038 for 1-day, 2-hour and 2-week, respectively).

For corneal and conjunctival chemical thresholds, there were no significant differences between visits in phase I (both P > 0.05, ANOVA).

Effect of Lens–Solution Interactions on Corneal and Conjunctival Sensitivity

Corneal and conjunctival thresholds to tactile, pneumatic mechanical, and chemical stimulation for phase II are summarized in Table 2.

Corneal chemical thresholds were significantly different between the MPSs, regardless of visit (P = 0.049, ANOVA). The threshold with the PHMB-preserved solution was lower than that of the Polyquad/Aldox system. There was a significant difference in corneal chemical thresholds between visits averaged across solutions (P = 0.043, ANOVA). The threshold at 1 week was lower than that at baseline (with Aosept; Tukey HSD, P = 0.025). However, the interaction between solution and visit was not significant (P > 0.05, ANOVA).

Conjunctival chemical threshold in phase II appeared to be lower with the PHMB-preserved solution than with the Polyquad/Aldox system. However, the difference was not statistically significant (P > 0.05, ANOVA). There was a significant interaction between solution and visit (P = 0.039, ANOVA). At the 2-hour visit on day 1 and the 1-week visit, there were significant differences between the two MPSs (Tukey HSD, both P = 0.049; lower threshold with the use of PHMB-preserved solution.

For tactile and pneumatic mechanical thresholds, there were no significant differences between solutions and visits and no solution and visit interactions in phase II (all P > 0.05, ANOVA).

TABLE 2. Corneal and Conjunctival Tactile, Pneumatic Mechanical, and Chemical Thresholds in Phase II

<table>
<thead>
<tr>
<th>Lens/Preservative</th>
<th>Tactile (mm/g/s)</th>
<th>Pneumatic Mechanical (Air Flow mL/min)</th>
<th>Chemical (%CO₂ Added)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cornea</td>
<td>Conjunctiva</td>
<td>Cornea</td>
</tr>
<tr>
<td>PV+Polyquad/Aldox-preserved system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (Aosept)</td>
<td>35.5 ± 19.0</td>
<td>123.9 ± 33.3</td>
<td>50.4 ± 25.9</td>
</tr>
<tr>
<td>Day 1, 2 h</td>
<td>35.1 ± 17.2</td>
<td>125.6 ± 31.2</td>
<td>46.6 ± 25.7</td>
</tr>
<tr>
<td>Day 1, 8 h</td>
<td>34.2 ± 20.3</td>
<td>126.6 ± 32.6</td>
<td>45.0 ± 24.8</td>
</tr>
<tr>
<td>Week 1, 2 h</td>
<td>33.9 ± 18.1</td>
<td>120.7 ± 27.5</td>
<td>44.3 ± 21.7</td>
</tr>
<tr>
<td>PV+PHMB-preserved system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (Aosept)</td>
<td>34.2 ± 16.5</td>
<td>121.9 ± 36.7</td>
<td>46.2 ± 26.5</td>
</tr>
<tr>
<td>Day 1, 2 h</td>
<td>34.6 ± 16.3</td>
<td>122.6 ± 35.1</td>
<td>44.6 ± 28.5</td>
</tr>
<tr>
<td>Day 1, 8 h</td>
<td>36.9 ± 18.6</td>
<td>121.8 ± 33.7</td>
<td>43.5 ± 24.8</td>
</tr>
<tr>
<td>Week 1, 2 h</td>
<td>36.0 ± 18.7</td>
<td>124.2 ± 33.4</td>
<td>45.6 ± 25.8</td>
</tr>
</tbody>
</table>

Data are expressed as the mean ± SD.
In the present study, conjunctival sensitivity to pneumatically mechanical stimulation increased from the no-lens baseline after the refitting of the SH lenses and a similar trend but smaller magnitude was observed in the cornea, suggesting an altered sensory processing of the ocular surface. This increase in sensitivity appeared to be transient (i.e., greater at the 2-hour and day-1 visits for conjunctiva and cornea, respectively). Stapleton et al.\(^{31}\) compared the effects of short-term SH and hydrogel lens wear on ocular surface sensitivity in neophytes and found that conjunctival sensitivity increased after the wear of SH lenses. The mechanism that leads to this increase in sensitivity to mechanical stimuli is unclear. Contact lenses applied to the eye can introduce stimulation due to friction on the ocular surface, particularly during the initial phase of wear.\(^{37}\) This mechanical effect may be greater with SH lens materials because of their relative high elastic modulus.\(^{37}\) In addition, the structure and physiology of the tear film can be altered during lens wear.\(^{2,54,55,56}\) The combination of these factors may lead to an increase in sensory input from the ocular surface, signaling the temporary disequilibrium between the components of the functional unit. Moreover, subclinical conjunctival inflammation that has been detected in asymptomatic contact lens wearers\(^{39}\) is likely to be another contributing factor, as the activities of the sensory nerve could be modified by injury and inflammatory mediators.\(^{4}\)

The change in mechanical sensitivity with SH lens wear in the present study was more pronounced in the conjunctiva. The conjunctiva is not only supplied by free nerve endings to provide sensory input to the functional unit, as in the cornea, but is also a highly reactive tissue.\(^{48}\) It is richly supplied by blood vessels, connected to the lymphatic system, and filled with immunocompetent cells.\(^{46}\) In addition, the conjunctiva is directly involved in regulating the secretion of components of the tear film, such as electrolytes, water, and mucin.\(^{31,42}\) and has a large area covering the ocular surface. It is conceivable that the conjunctiva would be sensitive to any changes occurring on the ocular surface, including the effects of contact lens wear.

In comparison, corneal tactile sensitivity decreased after SH lens wear from the no-lens-wear baseline, which is similar to previous reports with hydrogel lens wear.\(^{16,21,23}\) The reduction in corneal sensitivity with low-Dk hydrogel lens wear has been attributed to metabolic impairment resulting from lens-induced hypoxia.\(^{21,25}\) SH lens materials have diminished the lens-induced hypoxic impact on corneal physiology, with resulting improvement of a number of physiological markers, especially when lenses are worn overnight.\(^{43-45}\) If hypoxia and mechanical stimulation are responsible for lens-induced alteration in sensitivity but hypoxia effects have been minimized, the mechanism reducing tactile sensitivity with SH lens wear may be due to mechanical stimulation. Adaptation, the reduction in sensitivity after repeated suprathreshold stimulation, is a phenomenon that occurs in a variety of forms in sensory conditions.

### Table 3. Grading of Corneal and Conjunctival Staining in Phase I

<table>
<thead>
<tr>
<th>Lens Wear</th>
<th>Cornea (Mean % Area ± SD)</th>
<th>Conjunctiva (Median % Area; 10th, 90th Percentiles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitual</td>
<td>7.5 ± 18.6</td>
<td>4.0 (1, 9)</td>
</tr>
<tr>
<td>None</td>
<td>1.6 ± 4.4</td>
<td>1.0 (0, 4)</td>
</tr>
<tr>
<td>PV + Aosept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1, 2 h</td>
<td>1.5 ± 2.2</td>
<td>2.5 (0, 7)</td>
</tr>
<tr>
<td>Day 1, 8 h</td>
<td>2.3 ± 3.6</td>
<td>3.0 (1, 7)</td>
</tr>
<tr>
<td>Week 2.2 h</td>
<td>1.8 ± 2.9</td>
<td>3.0 (0, 6)</td>
</tr>
</tbody>
</table>

### Table 4. Grading of Corneal and Conjunctival Staining in Phase II

<table>
<thead>
<tr>
<th>Visit</th>
<th>Polyquad/Aldox System</th>
<th>PHMB-Preserved System</th>
<th>Polyquad/Aldox System</th>
<th>PHMB-Preserved System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.5 ± 2.0</td>
<td>1.8 ± 3.0</td>
<td>2.0 (0, 6)</td>
<td>3.0 (0, 6)</td>
</tr>
<tr>
<td>Day 1, 2 h</td>
<td>1.6 ± 2.4</td>
<td>29.5 ± 32.5</td>
<td>2.0 (0, 5)</td>
<td>5.0 (1.9)</td>
</tr>
<tr>
<td>Day 1, 8 h</td>
<td>5.7 ± 9.9</td>
<td>20.3 ± 25.1</td>
<td>3.0 (1.5)</td>
<td>4.5 (1.8)</td>
</tr>
<tr>
<td>Week 1, 2 h</td>
<td>4.7 ± 7.5</td>
<td>49.9 ± 39.9</td>
<td>3.0 (1.6)</td>
<td>6.0 (2.10)</td>
</tr>
</tbody>
</table>
systems. Functionally, adaptation may help to optimize the dynamic range of encoding in a neural system by shifting the sensitivity, and it develops and recovers depending on the time course of the stimulation. Although subjects in the present study were adapted daily contact lens wearers, temporary cessation of lens wear and therefore the withdrawal of the mechanical stimulus may have allowed some recovery and therefore no adaptation to the lenses, as shown in Table 1. After the subject was refitted with SH lenses, the close interaction between the lens and the cornea produced a sustained stimulation of the surface and adaptation, resulting in a shift in corneal sensitivity to the tactile stimuli.

In addition to the changes in pneumatic mechanical and tactile sensitivity with SH lens wear, ocular surface chemical sensitivity seemed to reflect the interaction between SH lens materials and MPS in this study. The higher levels of corneal surface staining induced by the solution preserved with PHMB were accompanied by an increased chemical sensitivity. This result is different from the decreased tactile sensitivity in solution-induced staining reported by Epstein. Comparison between the two studies is difficult to make, because of differences in study design, lens materials, and stimulus modality used. Even though the exact mechanism causing lens-solution interaction-induced staining remains unclear, the presence of this type of staining indicates an alteration in the ocular surface (Muya L, et al. IOVS 2008;49:ARVO E-Abstract #4809) that may have an impact on the sensory input (or vice versa) to the functional unit. This increased chemical sensitivity suggests sensitization of the polymodal nociceptors (or chemoreceptors) of the ocular surface. Sensitization, a reduction in threshold to one or more stimulus modalities and/or the development of lower-frequency spontaneous activity, can be caused by repeated noxious stimuli, such as inflammatory mediators on the ocular surface. This sensitization makes the polymodal receptors excitable by non-noxious stimuli and enhances the magnitude of their response to noxious stimuli. Many components in ophthalmic solutions have the potential to induce inflammatory changes on the ocular surface, and in the present study, the combination of lens and solution may have acted as exogenous chemical stimuli of the ocular surface, triggering a cascade of events and resulting in enhanced responsiveness of the polymodal receptors. More studies are warranted to explore the pathway and mechanism of sensitivity changes induced by this lens–solution interaction.

In the present study, we found different profiles of the changes in ocular surface sensitivity with lens wear and lens–solution combinations, when measuring with different stimuli from the twoesthesiometers used. The basis for the discrepancies between the two types of sensitivity measurement is not fully understood. It has been suggested that the stimulus delivered by the Cochet-Bonnet esthesiometer selectively activates mechanonociceptors that are responsible for the acute, sharp pain induced by direct mechanical contact with the ocular surface. On the other hand, the pneumatic stimulation may activate both mechno- and polymodal nociceptors. More recently, it has been proposed that a series of labeled lines consisting of neurons in the spinothalamic tract (the pain-signaling pathway to the brain) signal the homeostatic state of the body (interoception), whereas the pathways processing exteroceptive information (i.e., potentially dangerous stimuli impinging on our body) associated with pain may be different.

In addition, studies have suggested that cornea-responsive neurons in the spinal trigeminal nucleus, the subnucleus interpolaris/caudalis transition (Vi/Vc) and the subnucleus caudalis/upper cervical cord transition (VC/C1), process corneal input differently, and perhaps serve different nociception functions. Therefore, in addition to being related to differences between the twoesthesiometers such as stimulus modality, this dissimilarity between tactile and pneumo-

References

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