Effect of Punctal Occlusion on Tear Menisci in Symptomatic Contact Lens Wearers

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Purpose: To investigate by ultrahigh resolution optical coherence tomography the effect of punctal occlusion on tear menisci in symptomatic and asymptomatic contact lens wearers.

Methods: Symptomatic subjects with self-reported dry eyes (n = 20) and asymptomatic subjects (n = 20) were recruited. For each subject, 1 eye was randomly chosen for both upper and lower punctal occlusion with collagen plugs. Ultrahigh resolution optical coherence tomography imaged both upper and lower tear menisci before punctal occlusion, and 1, 4, 7, and 10 days afterward. Comfort scoring, noninvasive tear break-up time, tear break-up time, and Schirmer test with anesthesia were also performed.

Results: Tear meniscus variables in the symptomatic group were lower than those in the asymptomatic group (P < 0.05) at all time points except for day 4. In the symptomatic group, the tear menisci were increased up to day 4 after punctal occlusion (P < 0.05). The increase was present only on day 1 in the asymptomatic group. Improvement of comfort scores and noninvasive tear break-up time occurred in both groups after occlusion (P < 0.05). The comfort scores were linearly correlated with the tear volumes after punctal occlusion, with higher correlation coefficients in the symptomatic group.

Conclusions: Punctal occlusion transiently increased tear menisci in symptomatic and asymptomatic lens wearers, with a longer duration in the symptomatic group. For both symptomatic and asymptomatic lens wearers, the increased meniscus volume was associated with improved ocular comfort.

Key Words: tear menisci, ultrahigh resolution optical coherence tomography, contact lens, comfort, punctal occlusion

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MATERIALS AND METHODS

This prospective study was approved by the Office of Research Ethics, Wenzhou Medical College, Wenzhou, Zhejiang, China. Written informed consent was obtained from each subject, who was treated in accordance with the tenets of the Declaration of Helsinki. Study candidates who were adapted soft contact lens wearers were screened by a survey of general and ophthalmologic history, slit-lamp biomicroscopy, tear break-up time (TBUT), fluorescein staining, and Schirmer test with anesthesia. Each subject was also asked to rank ocular comfort using a dry eye questionnaire that consisted of 8 questions designed by Lin et al.23

Forty participants were recruited and categorized into 2 groups: the symptomatic group consisted of 20 subjects with complaints of dryness during lens wear (16 women and
4 men, mean ± SD age: 22.1 ± 3.5 years). Dryness complaints were defined as self-reported 1 or more symptoms that occurred often or continuously according to the questionnaire. The asymptomatic group was composed of 20 lens wearers (17 women and 3 men, age: 23.3 ± 3.0 years) who were without any dry eye symptoms. All subjects had no current ocular or systemic diseases such as conjunctival, scleral, or corneal diseases; glaucoma; diabetes mellitus; or connective tissue disease. Subjects were excluded if they had a history of eye surgery, trauma, hard contact lens wear, or taking antidepressant or diuretic medication.

A UHR-OCT instrument with high speed was custom developed at the Wenzhou Medical College. The configuration of the device was similar to the one described in previous studies. Briefly, a 3-module superluminescent diode light source was used with a center wavelength of 840 nm and a full width at half maximum bandwidth at 100 nm. The power of the incident light delivered into the eye was set to a safe level of 750 μW. The calibrated axial resolution of the system was ~3 μm in tears or tissues of the eye. The scan width was up to 15 mm, with a depth range of 3 mm in air. The scan was set to image the tear meniscus at the vertical meridian across the corneal apex, indicated by the specular reflection (Fig. 1). The room was maintained at 15 to 25°C and 30% to 50% relative humidity, and the light was dimmed to avoid possible reflex tearing.

Custom software was used to obtain upper tear meniscus height, upper tear meniscus cross-sectional area, lower tear meniscus height (LTMH), and lower tear meniscus cross-sectional area. Upper tear meniscus volume (UTMV) and lower tear meniscus volume (LTMV) were calculated based on the lid length and meniscus area. The total tear meniscus volume (TTMV) was the sum of UTMV and LTMV.

The comfort level was examined by a questionnaire with a continuous analogue scale from 0 to 50. Higher scores reflected comfort and little to no symptoms, and lower values reflected poor comfort of dry or gritty eyes.

Pre-lens tear stability was measured by non invasive tear break-up time (NIBUT) using the Keeler Tearscope with a grid filter (Keeler, Windsor, United Kingdom). The tearscope was mounted on a slit-lamp biomicroscope and connected to a TV monitor. The subject was positioned in front of the slit lamp and looked centrally into the tearscope. The subject was instructed to hold the eye open as long as possible while the investigator searched for the first discontinuity of the reflection of the grid from the contact lens on the TV monitor. The time between the last blink and the appearance of the first discontinuity or the initiation of a reflex blink was recorded. Three readings were taken and averaged. No fluorescein was used during the examination.

Tear film stability was also evaluated by TBUT. A fluorescein-impregnated strip (Jingming, Tianjing, China) wetted with saline solution was placed in the lower conjunctival sac. The time between full eye opening after a blink and the appearance of the first visible black spot in the stained tear film was noted. Three readings were taken and averaged.

Tear production was estimated by the Schirmer test with anesthesia. Five minutes after instillation of a drop of proparacaine (Alcon, Puurs, Belgium), a dry Schirmer test strip (Jingming) was placed over the lower lid margin into the tear lake. The strip was positioned at the junction of the middle and lateral one third of the lower lid to avoid corneal stimulation. After 5 minutes, the amount of wetting in millimeters was recorded as the Schirmer test score.

Hydrogel contact lenses (Acuvue; Johnson & Johnson Vision Care Inc, Jacksonville, FL) were provided to all subjects according to each individual’s own prescription. Each subject was asked to insert the contact lens at the same time every morning and wear the contact lens at least 8 hours every day during the study period. After wearing the study lenses for 1 week to become acclimated to them, ocular comfort was ranked in all subjects, and the results were used to classify them into asymptomatic and symptomatic groups. All subjects were tested at the same time of day, between 5:00 PM and 9:00 PM. During the baseline visit (day 0), after the 1-week lens acclimation period, upper and lower tear meniscus imaging, comfort scoring, NIBUT, TBUT, and Schirmer tests were performed in both eyes of each subject by a masked examiner. After that, each subject was taken to a consulting room by 1 of the 2 coexaminers (L.C. and Z.C.). Five minutes after topical anesthesia with proparacaine (Alcon), the subjects were instructed to position in front of the slit lamp, and they were asked to look away from the point of insertion. The traction of eyelids was applied with cotton-tip applicators while sterile forceps were used to insert absorbable collagen plugs (Lacrimedics Inc, Eastsound, WA) into the upper and lower puncta of a randomly selected eye. All collagen plugs were absorbable in 4 to 7 days and were 0.3 or 0.4 mm in diameter and 1.75 mm in length. The diameter of each plug was selected based on the best fit for each individual punctum. At follow-up visits on days 1, 4, 7, and 10 days after punctal occlusion, all examinations were repeated.

Data were analyzed by Statistical Package for the Social Sciences (version 16.0 for Windows XP; SPSS Inc, Chicago, IL) and presented as means ± SDs. Independent sample t tests were performed for comparison of variables between groups. Repeated measurement analysis of variance and post hoc test analysis were used to determine if there were differences in the tear menisci and other signs among the different visits. For all analyses, a level of P < 0.05 was considered statistically significant.

RESULTS

The heights, areas, and volumes of both upper and lower tear menisci and TTMVs in the symptomatic group were lower than those in the asymptomatic group at baseline before punctal occlusion (independent sample t test, P < 0.05 for each comparison; Table 1; Figs. 1–3). These differences were maintained after punctal occlusion except for day 4 (P > 0.05). In the symptomatic group, the increase in height, area, and volume for both upper and lower tear menisci and TTMVs was evident on days 1 and 4 compared with the baseline. In contrast, these variables were increased only on day 1 in the asymptomatic group (P < 0.05). Tear menisci variables in the symptomatic group reached the...
baseline levels of the asymptomatic group on days 1 and 4 ($P > 0.05$; Table 1; Figs. 2, 3).

The comfort scores in the symptomatic group were significantly lower than those in the asymptomatic group at each time point (independent sample $t$ test, $P < 0.05$; Table 1; Fig. 3A). Comfort scores for symptomatic subjects were improved for up to 7 days after occlusion (post hoc test, $P < 0.05$). In contrast, for the asymptomatic group, the comfort scores were increased only on day 1 (post hoc test, $P < 0.05$). Among the subjects in both groups, the comfort scores were linearly correlated with the UTMV, LTMV, and TTMV after punctal occlusion (Pearson correlation, $r$ range: 0.327–0.680,

**FIGURE 1.** Upper and lower tear menisci before and after punctal occlusion. UHR-OCT was used to detect both upper and lower tear menisci on the contact lens around the upper and lower eyelids. Images were acquired from symptomatic (A–E) and asymptomatic subjects (F–J) before punctal occlusion (A, F) and at days 1 (B, G), 4 (C, H), 7 (D, I), and 10 (E, J) afterward. The cornea (CO), contact lens (CL), and upper tear menicus (UTM) around the upper eyelid (UL) and lower tear meniscus (LTM) around the lower eyelid (LL) were clearly visualized. Bars = 500 μm.
The correlation coefficients of comfort scores and the tear meniscus volumes in the symptomatic group (range: 0.580–0.680, \( P < 0.001 \)) were higher than those in the asymptomatic group (range: 0.327–0.459, \( P < 0.001 \)).

The changes of variables were defined as the difference values between preocclusion baseline and the other 4 time points after punctal occlusion for all subjects. In the symptomatic group, the changes of TTMV were linearly correlated with the changes of comfort scores, NITUBT, TBUT, and Schirmer test at a different day after punctal occlusion (Fig. 4). In contrast, the relationships were present only for comfort scores and NITBUT in the asymptomatic group (Figs. 4A, B). The changes of TTMV at each checkpoint over the study period were not related to the baseline TTMV in both groups (\( P > 0.05 \)).

The preocclusion NITBUT and TBUT values were both higher in the asymptomatic group than in the symptomatic group (independent sample \( t \) test, \( P < 0.05 \); Table 1; Figs. 5A, B). After punctal occlusion, NITBUT for the asymptomatic group increased only on day 1 and then returned to baseline levels (Table 1; Fig. 5A). TBUT in the asymptomatic group did not change during the postocclusion period (post hoc test, \( P > 0.05 \); Table 1; Fig. 5B). For the symptomatic group, NITBUT was significantly increased up to 4 days after occlusion (post hoc test, \( P < 0.05 \); Fig. 5A), and TBUT was higher than baseline for up to 7 days (post hoc test, \( P < 0.05 \); Fig. 5B).

Schirmer test scores in the symptomatic group were significantly lower than those in the asymptomatic group (independent sample \( t \) test, \( P < 0.05 \); Table 1; Fig. 5C) through the study period. After punctal occlusion, the

### TABLE 1. Tear Meniscus Variables, Schirmer I Test Scores, TBUT, NITBUT, and Ocular Comfort Before and After Punctal Occlusion in Symptomatic Contact Lens Wearers and Asymptomatic Subjects

<table>
<thead>
<tr>
<th></th>
<th>Day 0</th>
<th>Day 1</th>
<th>Day 4</th>
<th>Day 7</th>
<th>Day 10</th>
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<tbody>
<tr>
<td>LTMH (( \mu m ))</td>
<td></td>
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<tr>
<td>Symptomatic</td>
<td>177 ± 20*</td>
<td>224 ± 31†</td>
<td>217 ± 50†</td>
<td>183 ± 23*</td>
<td>175 ± 21*</td>
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<tr>
<td>Asymptomatic</td>
<td>220 ± 21</td>
<td>284 ± 31†</td>
<td>225 ± 26</td>
<td>220 ± 24</td>
<td>215 ± 24</td>
</tr>
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<td></td>
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<tr>
<td>Symptomatic</td>
<td>9680 ± 2403*</td>
<td>15,255 ± 3694*</td>
<td>15,303 ± 6323†</td>
<td>11,336 ± 3399*</td>
<td>9347 ± 2288*</td>
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<tr>
<td>Asymptomatic</td>
<td>14,361 ± 2481</td>
<td>22,762 ± 4672†</td>
<td>15,019 ± 3120</td>
<td>14,104 ± 2586</td>
<td>13,597 ± 2306</td>
</tr>
<tr>
<td>LTMV (( \mu L ))</td>
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<tr>
<td>Symptomatic</td>
<td>0.33 ± 0.09†</td>
<td>0.52 ± 0.14*†</td>
<td>0.52 ± 0.21†</td>
<td>0.38 ± 0.12*</td>
<td>0.31 ± 0.08*</td>
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<tr>
<td>Asymptomatic</td>
<td>0.48 ± 0.08</td>
<td>0.76 ± 0.16†</td>
<td>0.50 ± 0.10</td>
<td>0.47 ± 0.08</td>
<td>0.45 ± 0.07</td>
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<td>UTBH (( \mu m ))</td>
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<tr>
<td>Symptomatic</td>
<td>160 ± 15*</td>
<td>203 ± 31*†</td>
<td>201 ± 37†</td>
<td>169 ± 21*</td>
<td>159 ± 18*</td>
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<tr>
<td>Asymptomatic</td>
<td>194 ± 11</td>
<td>249 ± 29*†</td>
<td>195 ± 18</td>
<td>189 ± 15</td>
<td>193 ± 15</td>
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<tr>
<td>Symptomatic</td>
<td>7643 ± 1395*</td>
<td>11,765 ± 2684*</td>
<td>11,830 ± 3374†</td>
<td>8513 ± 1345*</td>
<td>7734 ± 1366*</td>
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<tr>
<td>Asymptomatic</td>
<td>11,656 ± 2601</td>
<td>17,394 ± 3416†</td>
<td>11,667 ± 2685</td>
<td>11,307 ± 3057</td>
<td>11,759 ± 2700</td>
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<tr>
<td>LTMV (( \mu L ))</td>
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<tr>
<td>Symptomatic</td>
<td>0.23 ± 0.05*</td>
<td>0.36 ± 0.10*†</td>
<td>0.36 ± 0.11†</td>
<td>0.26 ± 0.05*</td>
<td>0.24 ± 0.05*</td>
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<tr>
<td>Asymptomatic</td>
<td>0.36 ± 0.08</td>
<td>0.53 ± 0.11†</td>
<td>0.36 ± 0.08</td>
<td>0.35 ± 0.09</td>
<td>0.36 ± 0.08</td>
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<tr>
<td>TTMA (( \mu L ))</td>
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<tr>
<td>Symptomatic</td>
<td>0.56 ± 0.13†</td>
<td>0.88 ± 0.22*†</td>
<td>0.88 ± 0.32†</td>
<td>0.64 ± 0.15*</td>
<td>0.55 ± 0.11*</td>
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<tr>
<td>Asymptomatic</td>
<td>0.84 ± 0.14</td>
<td>1.29 ± 0.25†</td>
<td>0.86 ± 0.17</td>
<td>0.82 ± 0.16</td>
<td>0.81 ± 0.14</td>
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<tr>
<td>Comfort score</td>
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<tr>
<td>Symptomatic</td>
<td>22 ± 8*</td>
<td>33 ± 7*†</td>
<td>29 ± 8*†</td>
<td>27 ± 7*†</td>
<td>23 ± 8*†</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>35 ± 7</td>
<td>41 ± 7*†</td>
<td>37 ± 7</td>
<td>36 ± 7</td>
<td>35 ± 7</td>
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<tr>
<td>NITBUT (s)</td>
<td></td>
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<tr>
<td>Symptomatic</td>
<td>2.8 ± 0.9*</td>
<td>4.3 ± 1.1*†</td>
<td>3.6 ± 1.0*†</td>
<td>2.9 ± 0.9*</td>
<td>2.8 ± 1.1*</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>4.4 ± 0.9</td>
<td>5.4 ± 0.9†</td>
<td>4.3 ± 0.9</td>
<td>4.3 ± 0.9</td>
<td>4.3 ± 0.8</td>
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<tr>
<td>TBUT (s)</td>
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<tr>
<td>Symptomatic</td>
<td>4.0 ± 1.2*</td>
<td>5.3 ± 1.3†</td>
<td>5.2 ± 1.6†</td>
<td>4.8 ± 0.8†</td>
<td>4.2 ± 0.9*</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>5.3 ± 1.2</td>
<td>5.6 ± 1.0</td>
<td>5.3 ± 1.1</td>
<td>5.3 ± 1.1</td>
<td>5.4 ± 1.1</td>
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<tr>
<td>Schirmer test (mm)</td>
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<tr>
<td>Symptomatic</td>
<td>3.0 ± 1.1*</td>
<td>3.7 ± 1.2*</td>
<td>3.1 ± 1.3*</td>
<td>3.0 ± 1.3*</td>
<td>3.0 ± 1.4*</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>6.6 ± 1.3</td>
<td>5.6 ± 1.1†</td>
<td>6.2 ± 1.4</td>
<td>6.3 ± 1.9</td>
<td>6.2 ± 0.8</td>
</tr>
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</table>

* \( P < 0.05 \) compared with asymptomatic subjects.
† \( P < 0.05 \) compared with preocclusion baseline.
LTMA, lower tear meniscus cross-sectional area; UTMA, upper tear meniscus cross-sectional area; UTMH, upper tear meniscus height.

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Schirmer test score for the asymptomatic group on day 1 was significantly lower than at baseline (post hoc test, \( P < 0.05 \); Table 1; Fig. 5C) but returned to the baseline values afterward. For the symptomatic group, there was no significant change in the postocclusion Schirmer test scores compared with the baseline (post hoc test, \( P > 0.05 \)).

**DISCUSSION**

The ocular menisci, along with tear secretion, distribution, evaporation, and drainage, play an important role in the dynamic balance of tears.\(^3^,3^,3^4\) The tear meniscus volume, which contains \( \sim 75 \) to \( 90\% \) of the total ocular surface tear volume,\(^3^5\) has been used in the evaluation and diagnosis of dry eye disease.\(^3^6,3^7\) The tear system and its balance may be disturbed by contact lens wear, resulting in ocular discomfort and dryness.\(^1^,2\) Tear meniscus volume is decreased in symptomatic contact lens wearers during short periods of soft contact lens wear, possibly causing ocular dryness.\(^1^1\) Since first described by Wang et al,\(^2^7\) OCT has proven to be a reliable, noncontact, noninvasive imaging method for simultaneously measuring and evaluating upper and lower tear variables.\(^2^8,3^0,3^6\) This method also works for quantifying tear meniscus volume during contact lens wear.\(^1^1,1^3\)

Insufficient tear volume may exist in self-reported dry eye symptomatic lens wearers. We found an increase of both upper and lower tear menisci in symptomatic lens wearers after punctal occlusion in the present study, which provides further evidence regarding the cause of dryness in these subjects. In a previous study of patients with dry eye disease who did not wear contact lenses, we used the same type of

![FIGURE 2. Preocclusion and postocclusion tear meniscus variables in asymptomatic and symptomatic contact lens wearers. Both upper and lower tear meniscus variables in the asymptomatic group were significantly lower than those in the asymptomatic group (\( P < 0.05 \)), except for day 4 after punctal occlusion. The tear meniscus variables in the symptomatic group were significantly increased on days 1 and 4 after punctal occlusion (\( P < 0.05 \)) but then returned to preocclusion levels on day 7. In contrast, a significant difference in tear meniscus variables in the asymptomatic group only occurred between baseline and day 1 after punctal occlusion (\( P < 0.05 \)). UTMH (A), upper tear meniscus height; LTMH (B); UTMA (C), upper tear meniscus cross-sectional area; LTMA (D), lower tear meniscus cross-sectional area; UTMV (E); LTVM (F). *\( P < 0.05 \) compared with asymptomatic subjects; †\( P < 0.05 \) compared with preocclusion baseline.

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plugs to occlude the upper and lower puncta. We found that the tear menisci returned to near normal levels by 1 day after occlusion. Similar results were reported by Farrell et al and Uchida et al. These data indicate insufficient baseline tear volumes in the symptomatic subjects whether or not they wore lenses. Punctal occlusion reduces tear drainage and thereby increases the tear meniscus volume. However, Lowerther and Sames, using a videotape procedure, found no change in the tear meniscus height after punctal occlusion in lens wearers with dry eyes. This may be because of tearing stimulated by the brightness of the slit-lamp light as it scanned the meniscus. Furthermore, it may be difficult to discern changes of tear menisci using only LTMH measured on a millimeter scale, which was the limit of resolution provided by videography. Thus, the use of noninvasive, noncontact UHR-OCT to measure upper and lower tear menisci simultaneously provides more precise measurement of the tear meniscus variables at micrometer resolution.

Wearing contact lenses may alter the response of the tear system to punctal occlusion. After occlusion, the meniscus volumes of the asymptomatic group increased for only 1 day, whereas those of the symptomatic group increased for 4 days. This suggests that different mechanisms for the 2 groups govern the response to punctal occlusion. These results were different from our previous study in which there were no changes in the tear menisci of normal subjects who were not wearing lenses. Based on those data, we inferred that there may be an autoregulatory response in the tear system that reduces tear secretion in response to reduced tear drainage. In addition, the higher flow as evident in the present study and lower tear osmolarity in the asymptomatic subjects may result in faster dissolution of collagen plugs compared with the symptomatic patients. Thus, tear meniscus volumes of the asymptomatic group return to baseline level faster than those of the symptomatic group.

It is possible that contact lenses play an important role in the tear system reaction to punctal occlusion. In contrast to the symptomatic lens-wearing subjects in this study, the tear meniscus volumes in the asymptomatic lens wearers increased for 1 day after punctal occlusion and then returned to the preocclusion level by day 4. This suggests that in these subjects, there might still be a self-adjustment mechanism, similar to subjects not wearing lenses, to keep the tear balance through reduced secretion, limiting the occurrence of epiphora. However, compared with the non-lens-wearing subjects, whose meniscus volumes did not change after occlusion, the autoregulation in the asymptomatic lens wearers may be somewhat impaired. The delayed autoregulatory

FIGURE 3. Ocular comfort scores and tear meniscus volumes. A, Comfort scores and TTMV before and after punctal occlusion in symptomatic contact lens wearers and asymptomatic subjects. TTMV in the symptomatic group was significantly increased through day 4 after punctal occlusion. For the asymptomatic group, the increase was present only for day 1. Symptom scores for symptomatic subjects were improved for up to 7 days after occlusion (P < 0.05), but in asymptomatic subjects, the increase lasted only 1 day (P < 0.05). Among the subjects in both groups, the comfort scores were linearly correlated with (B) TTMV, (C) UTMV, and (D) LTMV after punctal occlusion (P < 0.001). The correlation coefficients of comfort scores and the tear meniscus volumes in the symptomatic group were higher than those in the asymptomatic group. *P < 0.05 compared with asymptomatic subjects; †P < 0.05 compared with preocclusion baseline.
response in the asymptomatic lens wearers compared with those not wearing lenses might be because of the decreased sensitivity of the ocular surface. Secretion by the lacrimal glands is stimulated by the trigeminal nerve that innervates the ocular surface, adnexa, and nasal mucosa. Yen et al found that both ocular surface sensation and tear secretion decreased after temporary punctal occlusion, especially in normal subjects with both upper and lower puncta occluded. They suggested that punctal occlusion may affect the interaction between the ocular surface and the lacrimal gland. It is possible that the tear system may not be as sensitive to this ocular surface–lacrimal gland interaction after punctal occlusion in the adapted lens wearers with decreased ocular surface sensibility. Thus, both punctal occlusion and contact lenses might affect the autoregulatory mechanism that maintains tear balance. The decreased Schirmer test score for the asymptomatic subjects on day 1 also supports the idea of this autoregulation. The reduction of tear secretion was insufficient to offset the abrupt increase of the tear volume after punctal occlusion.

Consistent with other studies, we found that ocular comfort was correlated with meniscus volume. Chen et al reported the LTMV in symptomatic and asymptomatic contact lens wearers before lens insertion and during 10 hours of lens wear. They found the same correlation between ocular surface comfort and tear meniscus volume in symptomatic and asymptomatic experienced lens wearers and in normal inexperienced lens wearers. Thus, ocular comfort complaints increased as tear volume gradually decreased during lens wear. Mainstone et al found the same relationship between the tear volume and dryness complaints in patients with dry eye disease. Glasson et al reported a reduced LTMH in intolerant lens wearers compared with the tolerant lens wearers. Thus, the decreased tear volume may result in self-reported complaints among the contact lens wearers. In our study, there were significant correlations between the tear volumes and ocular discomfort in both groups, but the correlation coefficients in the symptomatic group were higher than those in the asymptomatic group. This indicates that ocular comfort in the symptomatic lens wearers was more sensitive to tear volume than that in the asymptomatic group.

NITBUT, which measures the prelens tear film stability, was correlated with the improvement of ocular comfort and tear meniscus. This is in agreement with a previous study by Wang et al who reported the same relationship between the NITBUT and the tear meniscus in healthy subjects. The increase of NITBUT may be attributed to
a change of the tear film thickness. This was consistent with the increased TBUT for up to 7 days in the symptomatic subjects, suggesting improvement of tear quality after occlusion. Tears are distributed from the meniscus during the blink to form the tear film that wets and smooths the surface of the cornea and contact lens. A larger tear meniscus is correlated with a thicker tear film.\(^{27}\)

We hypothesized that the increased tear meniscus may form a thicker prelens tear film and contribute to the improvement of the NITBUT and ocular comfort. Glasson et al.\(^3\) found that the NITBUT is reduced in intolerant lens wearers and can be one of the best measurements to predict contact lens intolerance. Decreased NITBUT may trigger the increase of tear evaporation that contributes to the reduced tear volumes and increased tear osmolarity, finally resulting in ocular discomfort. Thus, increased tear volume in the tear meniscus seems to contribute to the improvement of ocular comfort, possibly because of increased tear film stability as evident in the improved NITBUT.

There are some limitations in this study. First, the diameters of the plugs were 0.3 and 0.4 mm, but the puncta of each subject differed. However, we selected each plug according to the size of each individual punctum, and the increase of the tear menisci in both groups suggests that the punctal occlusion was successful. Second, the use of the same new contact lenses for all subjects eliminated confounding factors associated with different contact lenses for each subject, but the new lenses may have produced some variation in the results because of contact lens adaptation. However, allowing 1 week of adaptation to the new lenses minimized the impact of wearing them. Measurement and other errors have been previously discussed.\(^11,36\)

In summary, UHR-OCT is a suitable tool for evaluating the effect of punctal occlusion on tear meniscus. Based on the high-resolution imagery, lower UTMVs and LTMVs were evident in symptomatic lens wearers compared with the asymptomatic ones. Punctal occlusion increased tear menisci in both symptomatic and asymptomatic lens wearers, though the increase lasted longer for the symptomatic group. The delayed recovery of the tear meniscus to baseline levels in asymptomatic subjects suggests that the tear system self-adjustment mechanism may be partially impaired compared with normal subjects. For both symptomatic and asymptomatic lens wearers, the increased meniscus volume was associated with improved ocular comfort. The increased NITBUT after occlusion may also contribute to the ocular comfort.

**FIGURE 5.** Preocclusion and postocclusion NITBUT, TBUT, and Schirmer test scores in asymptomatic and symptomatic contact lens wearers. A, NITBUT was improved only on day 1 after occlusion in the asymptomatic group. For the symptomatic group, the improvement remained through day 4. B, TBUT did not change in the asymptomatic group over time compared with the baseline. For the symptomatic group, it was increased through day 7. C, Schirmer test scores did not change in the symptomatic group after punctal occlusion but decreased on day 1 postocclusion in the asymptomatic group. *\(P < 0.05\) compared with asymptomatic subjects; †\(P < 0.05\) compared with preocclusion baseline.
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REFERENCES
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