Punctal plugs versus artificial tears for treating dry eye: a comparative observation of their effects on contrast sensitivity

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Abstract This study aimed to compare the effects of treatment with punctal plugs versus artificial tears on visual function and tear film stability for dry eye. A total of 56 consecutive eyes of 28 dry eye patients observed at our clinic from May to October in 2009 were divided into two groups. One group (32 eyes of 16 patients) was treated with artificial tears, and punctal plugs were used in the other group (24 eyes of 12 patients). A questionnaire was used in these patients before treatment and was repeated 2 weeks after treatment. Fluorescent staining for tear film break-up time (BUT), the Schirmer test I (STI), and contrast sensitivity was performed at the same time. The questionnaire indicated that all patients complained about the uncomfortable symptoms associated with dry eye. These symptoms were relieved after the application of artificial tears or punctal plugs, and there was no significant difference between these two groups. We found that the corneal fluorescent staining disappeared after treatment. The BUT was improved significantly after treatment in both groups, but the improvement was greater in patients who received punctal plugs than those that received artificial tears. There was no remarkable change in the STI in the artificial tears group,

but a significant change was observed in the punctal plugs group. The contrast sensitivities were greatly improved in simulated daylight, night, and glare disability conditions after treatment with artificial tears and punctal plugs. However, the changes in contrast sensitivity did not significantly differ between groups. Both artificial tears and punctal plugs relieved dry eye symptoms, repaired corneal lesions, enhanced tear film stability, and improved contrast sensitivity. Punctal plugs could improve tear film stability and elongate the BUT better than artificial tears.

Keywords Dry eye · Punctal plugs · Artificial tears · Contrast sensitivity

Introduction

Dry eye is a tear film dysfunction involving a plethora of ocular discomforts varying from itching and burning to photophobia and pain. Blurred or fluctuating vision is also a frequent complaint in the dry eye population. Thus, a more recent area of dry eye study has focused on visual function evaluation and improvement. Dry eye patients who report decreased visual capability consistently have good results in ordinary clinical vision examinations, such as the Snellen chart, indicating that this most widely used visual assessment tool does not work well for individuals with dry eye. Previous studies have determined that contrast sensitivity is a more accurate evaluation of functional visual acuity than the Snellen chart because the former measures the ability to resolve subtle spatial differences in a low-contrast situation, which compared with the high-contrast targets in the Snellen chart, is more sensitive and also more similar to what people encounter in daily life [1, 2].

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Table 1 Contrast sensitivity in simulated daylight before and after artificial tears

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.74±0.142	1.87±0.190	1.89±0.253	1.47±0.294	1.13±0.241
After	1.79±0.159	1.97±0.166	2.01±0.238	1.62±0.288	1.24±0.282
<i>t</i>	−1.594	−3.407	−3.002	−2.403	−2.544
<i>P</i>	0.121	0.002	0.005	0.023	0.017

Precorneal tear film plays an essential role in forming a smooth and regular optical interface. Unstable tear film has been shown to have a detrimental effect on vision in dry eyes. Theoretically, treatment contributing to tear film stability may effectively improve the functional visual acuity of dry eye patients.

The treatment of dry eye depends on its severity and comprises a large range of therapeutic strategies [3]. Artificial tears and punctal occlusion are the two mainstays in dry eye treatment in China. The temporal improvement of visual function following the use of artificial tears has been shown by Huang et al., Liu et al., and Torkildsen [1, 4, 5]. Similar conclusions have also been reported for punctal plug insertion [6]. However, which treatment can improve visual function better in dry eye patients? To our knowledge, no published reports have compared these two treatments for their efficacy in improving contrast sensitivity and glare disability in dry eye patients. Therefore, we conducted this study to explore the differences between artificial tears and punctal plugs with respect to functional vision improvement. Their influences on dry eye symptoms and tear film quality were also analyzed.

Patients and methods

Patients

A total of 28 patients (10 males and 18 females) diagnosed with dry eyes at our ophthalmology clinic from May to October in 2009 were enrolled in this study after providing their informed consent. They were randomly assigned into artificial tears group (32 eyes of 16 patients) and punctal

plugs group (24 eyes of 12 patients). This study was approved by the institutional review board of Peking University Third Hospital and adhered to the tenets of the Declaration of Helsinki. The ages of the patients ranged between 22 and 67 years at the time of the study. The mean ages±standard deviations of the artificial tears group and the punctal plugs group were 32.1±12.8 and 31.4±15.1 years, respectively. The entry criteria for the patients were that they were diagnosed with dry eyes at our ophthalmology clinic and had no evidence of ocular diseases other than those associated with dry eye changes, such as superficial punctate keratopathy (SPK). The diagnosis of dry eye was made on the basis of (1) symptoms of dry eyes, (2) Schirmer I test results of less than 10 mm without anesthesia or less than 5 mm with topical 0.5 % proparacaine hydrochloride anesthesia, and (3) tear film break-up time of less than 5 s [1]. All patients underwent subjective optometry, and those whose visual acuity was less than 20/20 would be corrected to their best visual acuity, while those with hyperopia would be corrected to 20/20 during testing.

Measurements

All patients first completed a questionnaire regarding dry eye discomfort created by our team. Eight symptoms associated with dry eye were included: (1) dryness, (2) foreign body sensation, (3) visual fatigue, (4) burning, (5) red eye, (6) stinging, (7) secretion on eyelash, and (8) difficulty opening eyes in the morning due to dryness. The patients were required to score each symptom according to a scale of 1 to 10; 1 being the absence of the type of discomfort and 10 being the most severe level that one could bear.

Table 2 Contrast sensitivity in simulated night before and after artificial tears

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.87±0.162	1.89±0.238	1.78±0.300	1.23±0.250	0.85±0.263
After	1.89±0.147	1.95±0.210	1.88±0.288	1.48±0.291	1.00±0.243
<i>t</i>	−1.142	−1.546	−2.823	−4.167	−2.379
<i>P</i>	0.262	0.132	0.008	<0.001	0.028

Table 3 Glare disability before and after artificial tears

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.78±0.180	1.79±0.261	1.68±0.301	1.13±0.254	0.70±0.177
After	1.79±0.165	1.85±0.243	1.77±0.318	1.82±0.308	0.87±0.299
<i>t</i>	−0.43	−2.031	−1.872	−11.610	−2.854
<i>P</i>	0.668	0.051	0.071	<0.001	0.013

Each patient underwent corneal fluorescein staining to detect punctate epithelial keratopathy. The tear film break-up time (BUT) and the result of the Schirmer I test without anesthesia were recorded for each patient. All patients were examined by the same observer.

The OPTEC6500 functional vision testing system (Stereo Optical, Chicago, IL, USA) was used to measure contrast sensitivity and glare disability at five spatial frequencies: 1.5, 3, 6, 12, and 18 cycles per degree (cpd). All of the above examinations were repeated 2 weeks after artificial tear or punctal plug treatment.

Intervention

After completion of the baseline examinations, all patients were randomly divided into two groups. The artificial tears group (16 patients, 32 eyes) included patients treated with an artificial tear solution (Zhuhai Yisheng, Guangdong, China) containing a carbomer gel and bFGF. The plug group (12 patients, 24 eyes) included patients treated with the SmartPLUG500 (Medenium, Irvine, CA, USA), a thermo-sensitive punctal plug. Patients in the artificial tears group used the artificial tear solution four times per day, with one drop instilled each time into the inferior conjunctival sac of both eyes. Patients in the plug group underwent punctal plug insertion in both the superior and inferior lacrimal puncta. Two weeks later, all of the above examinations and the questionnaire were repeated. The artificial tears group used the artificial tears 10 min before the examination.

Statistical analysis

All data are shown as the mean±standard deviation. The paired Student's *t* test was used to identify the differences in

contrast sensitivity and glare disability at each spatial frequency within the group before and after the treatments. The unpaired *t* test was used to compare the mean values of contrast sensitivity and glare disability between the groups. A *P* value <0.05 was considered to be statistically significant.

Results

Questionnaire

All subjects reported dry eye symptoms. Dryness, foreign body sensation, visual fatigue, and red eyes were the four most frequent dry eye symptoms. Before treatment, the mean scores on the dry eye questionnaire were 52.4±8.4 for the artificial tears group and 54.4±6.2 for the plug group. The difference between the mean scores of the two groups was not significant (*P*=0.24, *t*=−0.81). Two weeks after treatment, the mean scores were 16.1±5.0 for the artificial tears group and 15.8±4.6 for the plug group. No significant difference was identified between the groups (*P*=0.082, *t*=−1.77). Within both groups, the results before and after treatment were significantly different (artificial tears group *t*=33.6, *P*<0.001; plug group *t*=49.7, *P*<0.001).

Corneal fluorescein staining

Apparent punctate epithelial keratopathies that stained with fluorescein were identified in 12 subjects, six in each group. After 2 weeks of treatment, the staining persisted in three subjects in each group. We prolonged the observation to 1 month and found no punctate epithelial keratopathy in either group.

Table 4 Contrast sensitivity in simulated daylight before and after punctal plug insertion

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.74±0.189	1.78±0.195	1.69±0.293	1.28±0.228	0.79±0.223
After	1.82±0.132	1.91±0.130	1.86±0.193	1.43±0.270	1.04±0.241
<i>t</i>	−2.313	−3.845	−5.618	−4.562	−5.423
<i>P</i>	0.03	0.01	<0.001	<0.001	<0.001

Table 5 Contrast sensitivity in simulated night before and after punctal plug insertion

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.80±0.143	1.74±0.240	1.51±0.306	1.11±0.239	0.68±0.151
After	1.84±0.099	1.85±0.174	1.69±0.226	1.21±0.258	0.92±0.272
<i>t</i>	−1.349	−4.45	−3.991	−2.163	−2.992
<i>P</i>	0.190	<0.001	0.001	0.045	0.014

Schirmer I test and tear film BUT

Before intervention, the mean Schirmer I test results were 12.1 ± 7.65 mm for the artificial tears group and 7.8 ± 2.62 mm for the plug group. Two weeks after the intervention, the Schirmer I test score increased to 14.4 ± 9.01 mm in the artificial tears group and 14.0 ± 3.39 mm in the plug group. The improvement within the plug group was obvious. No significant difference was found for the artificial tears group before and after treatment ($P=0.072$, $t=-1.865$). However, the before and after results for the plug group significantly differed ($P<0.01$, $t=-7.196$). There was a significant difference in the results following treatment between the two groups ($t=-2.196$, $P=0.032$).

Two weeks after the regular instillation of artificial tears, the BUT for the artificial tears group became 6.5 ± 1.1 s, which significantly differed from the before-drug result of 4.4 ± 1.1 s ($P<0.01$, $t=-8.96$); 2 weeks after punctal occlusion, the BUT for the plug group became 6.6 ± 1.3 s, which was significantly different from the before-plug result of 3.1 ± 1.5 s ($P<0.01$, $t=15.1$). The posttreatment improvement significantly differed between the two groups ($P<0.01$, $t=-4.44$).

Contrast sensitivity and glare disability

Artificial tears group

Table 1 shows the contrast sensitivities in the artificial tears group in simulated daylight (85 cpd/m^2) for each frequency. The contrast sensitivities increased significantly in all frequencies after the use of artificial tears, except for the

frequency of 1.5 cpd (1.5 cpd, $P=0.121$, others $P<0.05$). The contrast sensitivities in simulated night (3 cpd/m^2) at all frequencies before and after treatment with artificial tears are shown in Table 2. No significant difference after the use of artificial tears was reported at low frequencies (1.5 and 3 cpd). However, the contrast sensitivities rose greatly at intermediate and high-level frequencies (6, 12, and 18 cpd, all $P<0.05$), particularly at 12 cpd ($P<0.001$). The glare disability in dry eyes before and after the instillation of artificial tears is demonstrated in Table 3. Improved values were found at all spatial frequencies, although the difference was only statistically significant at 12 and 18 cpd (12 cpd, $P<0.001$; 18 cpd, $P=0.028$).

Plug group

The effects of punctal plugs on contrast sensitivity and glare disability are shown in Tables 4, 5, and 6. The insertion of punctal plugs resulted in significant changes in contrast sensitivity in both simulated day and night situations and also in the glare disability test. Sensitivities at all frequencies showed great improvements, but the difference at 1.5 cpd in a simulated night condition (3 cpd/m^2) was not statistically significant ($P=0.190$).

Comparison of the two groups

We compared the effects of artificial tears and punctal plugs on contrast sensitivity and glare disability. The results are listed in Tables 7, 8, and 9. The contrast sensitivity and glare disability improved in both groups, but the two groups did not significantly differ.

Table 6 Glare disability before and after punctal plug insertion

cpd	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Before	1.69±0.143	1.71±0.226	1.53±0.331	1.11±0.248	0.76±0.175
After	1.79±0.138	1.79±0.196	1.63±0.245	1.28±0.274	0.95±0.257
<i>t</i>	−3.111	−2.756	−2.238	−2.236	−3.044
<i>P</i>	0.005	0.011	0.036	0.045	0.016

Table 7 Improvements in contrast sensitivity for the two groups in simulated daylight

Improvement	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Artificial tears group	0.047±0.166	0.103±0.171	0.113±0.212	0.149±0.338	0.116±0.237
Plug group	0.074±0.157	0.130±0.167	0.168±0.144	0.146±0.150	0.249±0.183
<i>t</i>	−0.614	−0.585	−1.082	0.030	−1.927
<i>P</i>	0.542	0.561	0.284	0.976	0.061

Discussion

Recently, decreased or fluctuating visual acuity in dry eye has become one of the most common complaints observed by eye care practitioners. Tear film is a powerful refractive interface. Unstable tear film is incapable of maintaining a smooth precorneal surface, which has a detrimental impact on visual function and may negatively affect patient quality of life [7, 8]. The purpose of this study was to determine whether the administration of artificial tears or punctal plugs would improve contrast sensitivity better of a patient with dry eye presumably by increasing the stability of the tear layer.

Although both groups reported significant improvements in dry eye discomfort after treatment, no between-group differences were observed in the mean values of the dry eye questionnaire. Our results indicate that both treatments carry the same effectiveness for relieving ocular irritation caused by dry eye.

Following corneal fluorescein staining, all patients with punctate epithelial keratopathy in both groups were cured after 1 month of treatment, confirming that both treatments could repair corneal epithelial lesions caused by dryness. The Schirmer I test results of the plug group improved significantly and were significantly more improved than those in the artificial tears group, confirming the efficacy of the plugs in maintaining tear volume.

The tear film break-up time for both groups increased significantly, but it did not reach the normal level. The plug group, which had a lower BUT than the artificial tears group before treatment, had a higher mean value after intervention. The increases in the two groups were significantly different. The results indicate that both

therapies can enhance tear film stability, although the plugs appeared to be more effective.

We chose contrast sensitivity as the evaluation tool for visual function in our study because it was more sensitive for dry eyes. The testing device simulated three conditions: day, night, and glare. The simulated daylight was set as 85 cpd/m², and night was set as 3 cpd/m².

There are several studies that report improvement in the visual performance of patients with dry eye disease with the use of artificial tear solutions [9–11]. The results for the artificial tears group indicated that in the situations of both day and night, the contrast sensitivity at intermediate and high frequencies increased greatly, which is similar to the results of Liu's study [4]. The glare sensitivity demonstrated improvement at high frequencies only.

For the plug group, sensitivities at all frequencies in the three situations showed significant increases except for 1.5 cpd at night. The above data confirmed that both treatments could improve dry eye patients' visual functions, particularly at high frequencies. Although a comparison of the improved values in the two groups showed no significant differences, it appeared that plugs could improve the sensitivity at more frequencies, especially in glare disability mode. Knowledge of the disability glare of a subject as well as his or her contrast sensitivity completes the measure of visual quality. Tear film changes in dry eye patients may lead to irregularities on the corneal surfaces. Any irregularity in the ocular media can reduce contrast sensitivity and contribute to disability glare [12]. In the treatment of dry eyes, punctal occlusion not only improves the tear quality by increasing the aqueous component of the tear film and diminishing its osmolarity [13], but also preserves natural

Table 8 Improvements in contrast sensitivity for the two groups in simulated night

Improvement	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Artificial tears group	0.028±0.139	0.056±0.204	0.107±0.214	0.249±0.310	0.142±0.266
Plug group	0.036±0.132	0.123±0.137	0.175±0.210	0.106±0.209	0.234±0.267
<i>t</i>	−0.213	−1.463	−1.174	1.715	−0.975
<i>P</i>	0.832	0.149	0.246	0.093	0.338

Table 9 Improvements in the sensitivity of glare disability testing for the two groups

Improvement	Low (1.5)	Low (3)	Medium (6)	High (12)	High (18)
Artificial tears group	0.013±0.166	0.060±0.168	0.087±0.262	0.237±0.281	0.167±0.226
Plug group	0.099±0.155	0.083±0.145	0.107±0.225	0.167±0.268	0.192±0.187
<i>t</i>	−1.974	−0.518	−0.291	0.720	−0.286
<i>P</i>	0.053	0.606	0.772	0.477	0.777

tears, which are more regular and physiological for the ocular surface. Taking the transient effect of artificial tears into consideration, plug insertion has a more powerful and long-lasting effect on visual function in the dry eye population.

In summary, both treatments have the same efficacy in relieving ocular discomfort in dry eyes and have similar and effective repair functions for punctate keratopathy. Plugs increased tear volume and appeared to have a better effect on stabilizing tear film. Both artificial tears and punctal plugs improved dry eye visual function. However, compared with the transient effects of the eye drops, punctal plugs have a lasting impact on visual acuity.

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Conflict of interest The authors report no conflicts of interest.

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