

Assessment of tear film optical quality in a young short tear break-up time dry eye

Case-control study

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Abstract

Background: The aim of the study was to evaluate the dynamic changes of tear film optical quality in a short tear break-up time (TBUT) dry eye by using a double-pass system.

Methods: Thirty-five short TBUT dry eye participants and 43 control subjects without dry eye were included in this study. One eye for each subject was analyzed. The Objective Scatter Index (OSI), modulation transfer function (MTF), and strehl ratio (SR) were recorded within a 20-second period with the participants asked to blink freely, and 10 successive seconds of nonblinking immediately after a blink was recorded to analyze the tear film OSI. The mean tear film OSI in 10 successive seconds, Δ OSI, and Δ OSI/time were evaluated. The correlation between tear film OSI and MTF, and the correlation between tear film OSI and MIT were also analysed.

Results: Short TBUT dry eye participants showed significant deterioration of MTF and SR compared to control subjects. The mean tear film OSI in 10 successive seconds was significantly higher in dry eye participants than in control subjects. The mean OSI of the tear film (0–5 seconds) and the mean OSI of the tear film (6–10 seconds) were significantly higher in dry eye participants than in control participants. Moreover, the Δ OSI was significantly higher in dry eye participants than in control participants. The tear film OSI was significantly correlated with the MTF and the SR.

Conclusions: The tear film OSI of short TBUT dry eye participants is significantly increased in the early stage. Tear film instability in short TBUT dry eye participants has a significant effect on optical quality.

Abbreviations: ADES = Asia Dry Eye Society, MTF = modulation transfer function, OQAS = Optical Quality Analysis System, OSI = Objective Scatter Index, OSDI = Ocular Surface Disease Index, QoV = quality of vision, SAI = surface asymmetry index, SR = strehl ratio, SRI = regularity index, TBUT = tear break-up time.

Keywords: dry eye, optical quality, short tear break-up time, tear film

1. Introduction

The precorneal tear film is the first medium that modifies the optical path of the light that reaches the retina. Any local change in tear-film regularity and dynamic may cause both vision-related and ocular surface-related symptoms. The function of the intact tear film for the quality of optical imaging was early reported in the 1990s.^[1] Recent studies have shown the visual deterioration

and the changes of optical quality in patients with dry eye.^[2–5] Decreased quality of life and interference with the ability to drive were also observed in dry eye patients.^[6–8]

In 2016, the Asia Dry Eye Society (ADES) implemented new diagnostic criteria for dry eye that enabled diagnosis with only subjective symptoms and decreased tear break-up time (TBUT) (≤ 5 seconds). The tear film instability plays an important role in the pathophysiology of dry eye, as the unstable tear film is the pivotal mechanism of dry eye. The tear film forms the most anterior optical surface of the eye, which makes it critical for visual performance. Thus, the optical quality of the tear film is a vital component of a clear retinal image, and the effect of tear film on the optical quality deserves study.

In this study, we aimed to assess the dynamic change of the tear film in young short TBUT dry eye participants during the first 10 seconds after a blink, to investigate the influence of an unstable tear film on the optical quality of the eye.

2. Participants and methods

2.1. Participants

A total of 35 young short TBUT dry eye participants under the age of 40 were recruited from the Peking University People's hospital. The diagnosis of dry eye was based on the criteria made by the ADES, namely subjective symptoms and decreased TBUT (≤ 5 seconds).^[9] Forty-three age- and sex-matched control participants were also recruited. The study followed the

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The authors alone are responsible for the content and writing of the article.

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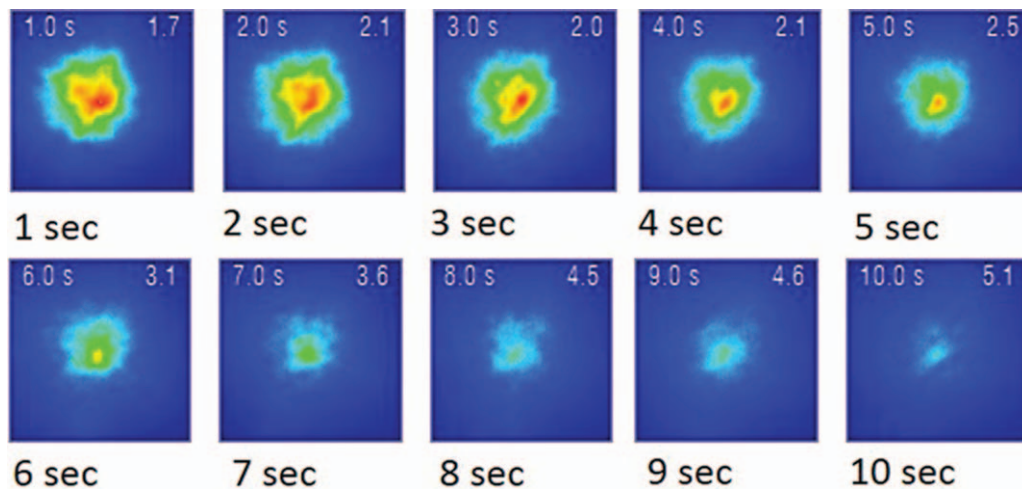


Figure 1. Example of the tear film analysis of one dry eye participants with OQAS showing the Objective Scatter Index (OSI) change during a period of 10 seconds. The upper left number is the time (seconds), the upper right number is the OSI value.

Declaration of Helsinki. Procedures were approved by the institute of Peking University People’s hospital. People who consented to participate in the study should sign the informed consent form.

All participants underwent the slit-lamp examination. The best corrected visual acuity for all participants was 20/20 or better. Participants were free of the ocular surface diseases such as blepharitis, keratitis, cornea opacities conjunctivitis, and topical medication history. Short TBUT dry eye participants with corneal staining were excluded from the group. The TBUT was measured by instilling fluorescein into the inferior palpebral conjunctiva, and the test result was the average of 3 measurements. Schirmer test was performed without anesthesia.

2.2. Measurement of tear film with double-pass system

Optical quality was evaluated by the double-pass Optical Quality Analysis System (OQASII; Visiometrics S.L., Tarrasa, Spain). The OQAS could correct the participants’s refractive error by the

instrument set internally (ranged from -8.00 to $+5.00$ diopters [D]). Astigmatism $\geq 0.75D$ was corrected by using external ophthalmic cylindrical lenses. The measurements were made in a dark room to achieve the largest possible natural pupil size. Participants were instructed to blink naturally twice and then keep the eyes open for at least 10 seconds. A successive 10 seconds of nonblinking immediately after a blink was selected to analyze. The examination was performed just after the blink, and sequences of double-pass images were recorded every 0.5 seconds. When one eye was measured, the other eye was patched. In this study, we selected the images at 1-second time intervals from 1 to 10seconds after a blink (Figs. 1 and 2).

The examination provided a graph that showed the Objective Scatter Index (OSI) change over 10seconds, and the curves are shown in Figure 3. For each participant, both eyes were measured and only 1 eye was selected randomly, and the serial measurements were recorded 3 times. Only well-recorded images taken between blinks were analyzed. The rate of change in the OSI ($\Delta OSI/time$) was done by comparing the OSI obtained just after

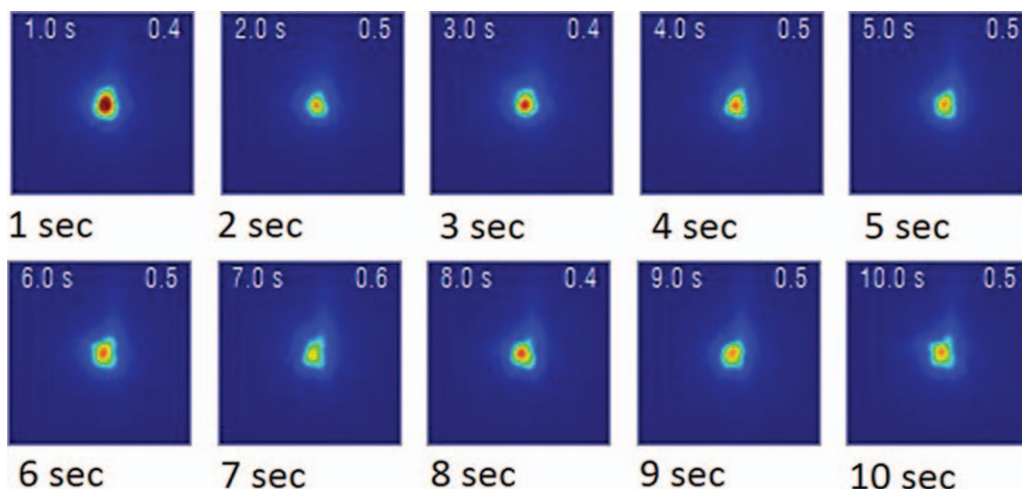


Figure 2. Example of the tear film analysis of one normal patient with OQAS showing the Objective Scatter Index (OSI) change over a period of 10seconds. The upper left number is the time (seconds), the upper right number is the OSI value.

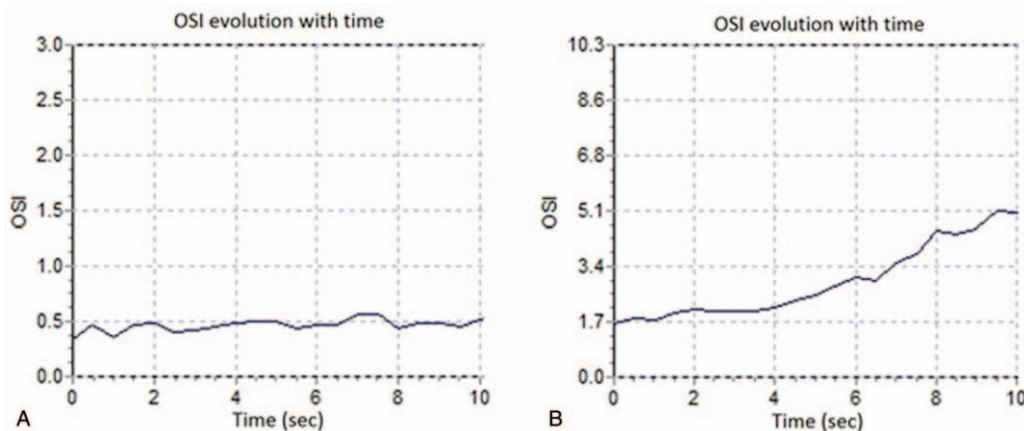


Figure 3. Example of the OSI change during a period of 10seconds. (A) A steady-low value of a normal patient. (B) An ascending-high value pattern of a dry eye patient. OSI=Objective Scatter Index.

blinking (0seconds) with the value obtained after 5seconds without blinking, such as the following equation: $\Delta OSI(0 - 5s) = OSI(5s) - OSI(0s)$; $\Delta OSI(0 - 5s)/time(5s) = \frac{OSI(5s) - OSI(0s)}{5s}$

The dynamic changes of the OSI values of the tear film and the optical quality indicators such as modulation transfer function (MTF) and strehl ratio (SR) were recorded automatic by the OQASII.

2.3. Statistical analysis

Data were analyzed using SPSS 20.0 (SPSS Inc., Chicago, IL). All values were expressed as mean±SD. Two sample *t* test and Pearson χ^2 test were used to compare values between the 2 groups. The correlation test was used to analyze the correlation between the tear film OSI and the optical quality parameters. A *P* value <.05 was considered significant.

3. Results

Thirty-five eyes from short TBUT dry eye participants and 43 eyes from control participants without dry eye were enrolled in the study. The participants’ characteristics and the parameters of dry eye and optical quality are shown in Table 1. There are no significant differences in sex ($\chi^2=1.171$; *P*=.279) and age (*P*=.09) between the 2 groups. Both MTF and SR are

significantly lower in the dry eye group than in the control group (*P*<.001; *P*<.001).

The OSI-related parameters of the tear film are shown in Table 2. Compared with control participants, the total tear film OSI and $\Delta OSI/time$ are significantly higher in short TBUT dry eye participants than control participants (*P*<.001). Figure 4 shows the change curve of the tear film OSI. The dry eye group shows an increasing curve after a blink, and there was significant difference between the OSI at 1 second and the OSI at 2seconds (*P*=.028) (Fig. 4B). The control group shows an increase in the first 1 second and becomes flat at 2 to 4seconds. There was significant difference between the OSI at 1 second and the OSI at 7seconds in the control group (*P*=.021) (Fig. 4A).

Figure 5 shows the change curve of the mean MTF over 10 seconds. The dry eye group shows a decreasing trend after a blink, meaning a substantial decrease in optical quality, and there was significant difference between the MTF at 1 second and the MTF at 4 second (*P*=.001) (Fig. 5B). The control group shows a decrease trend over the first 2seconds, and then at about 2 to 6 seconds, the curve is relatively flat. After the 6seconds, the curve shows a decreasing trend. There was a significant difference between the MTF at 1 second and the MTF at 10seconds (*P*=.013) (Fig. 5A).

Figure 6 shows the correlation between the tear film OSI and optical quality parameters. The tear film OSI was negative significantly correlated with the eye MTF (*r*=-0.708; *P*<.001) (Fig. 6A). The tear film OSI was negative significantly correlated with the eye SR (*r*=-0.939; *P*<.001) (Fig. 6B).

Table 1

Demographic information and clinical test results.

	Control, n=43	Dry eye, n=35	<i>P</i>
Male, n	9	16	
Female, n	26	27	.279*
Age, y	29.02±5.37	31.31±6.44	.09†
OSDI	5.05±3.60	7.46±5.03	.016†
TBUT, s	9.70±0.49	3.57±0.61	<.001†
Schirmer test, mm	13.16±6.91	11.51±8.38	.344†
Strehl ratio	0.201±0.051	0.149±0.039	<.001†
MTF cut-off, c/deg	34.695±8.609	26.340±8.460	<.001†

MTF= modulation transfer function, OSDI= Ocular Surface Disease Index, TBUT= tear break-up time.

* Pearson χ^2 test.

† Two-sample *t* test.

Table 2

Analysis of OSI-related parameters of the tear film.

Parameters	Control, n=43	Dye eye, n=35	<i>P</i>
Total OSI (0–10 s)	0.637±0.285	1.206±0.688	<.001
Mean OSI of the tear film (0–5 s)	0.118±0.155	0.599±0.474	<.001
Mean OSI of the tear film (6–10 s)	0.193±0.188	1.770±1.224	<.001
ΔOSI (0–5 s)/time (5 s)	0.008±0.017	0.133±0.132	<.001
ΔOSI (6–10 s)/time (5 s)	0.032±0.043	0.305±0.208	<.001
ΔOSI (0–10 s)/time (10 s)	0.020±0.024	0.218±0.148	<.001

ΔOSI = mean value of the OSI changes, $\Delta OSI/time$ = mean value of the OSI changes over time, OSI= Objective Scatter Index.

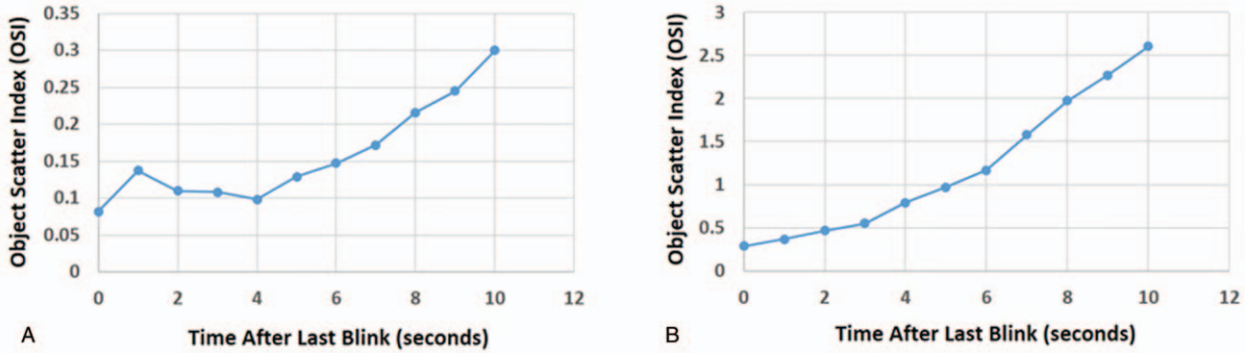


Figure 4. The mean Objective Scatter Index change during a period of 10seconds. (A) The normal group. (B) The dry eye group.

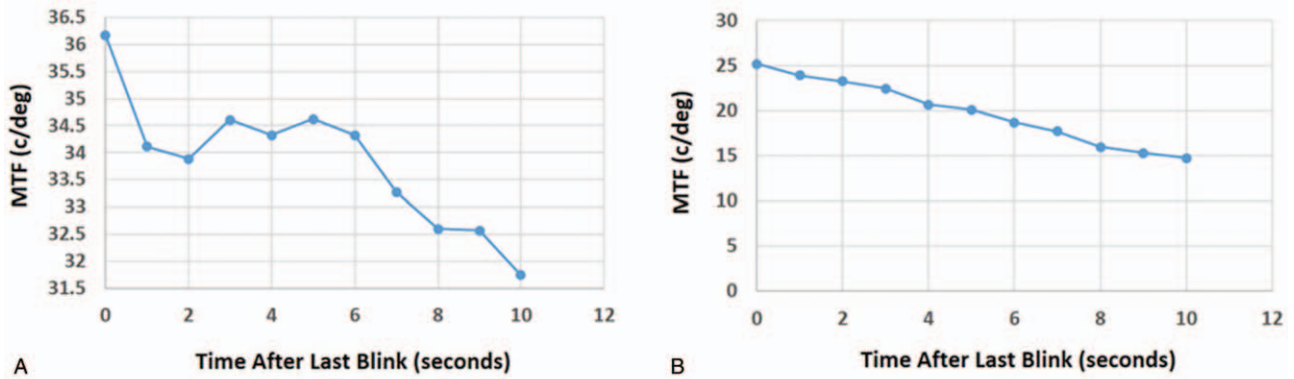


Figure 5. Mean MTF of the eye at 3 times after a blink (7.0-mm pupil) measured by a double-pass method. (A) The normal group. (B) The dry eye group. MTF = modulation transfer function.

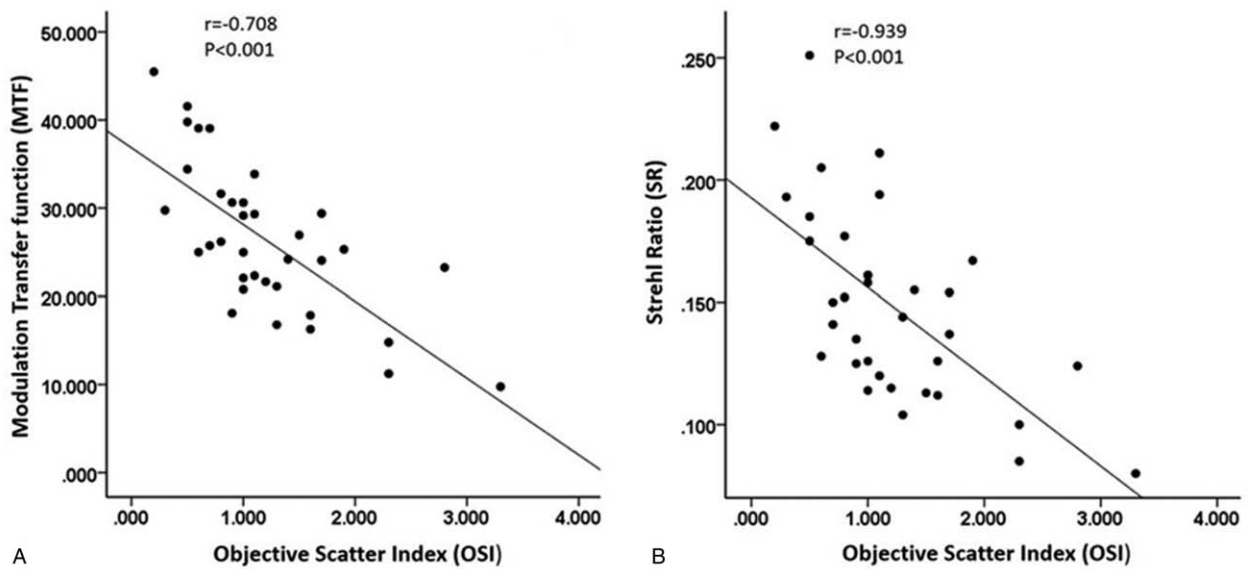


Figure 6. The correlations between Objective Scatter Index (OSI) and optical quality in the dry eye participant group. (A) The correlation between OSI and modulation transfer function. (B) The correlation between OSI and strehl ratio (SR).

4. Discussion

The optical quality depends on each isolated refractive component of the whole eye. The lens and the tear film are the variable factors of the refractive system. During the last few years, several studies had reported that the tear break-up reduced the optical quality.^[10–15] The tear break-up is a dynamic process and any local changes of the tear film after blink will cause changes of the optical quality. The purpose of the study is to investigate the pattern changes of tear film OSI and the optical quality of the whole eye in normal and short TBUT participants by using the double-pass Optical Quality Analysis System OQAS II.

The OSI is a measure of the amount of light that is scattered as it passes through the ocular structure.^[16] The changes in OSI values stem from tear film dynamic alterations, as the cornea, lens, and vitreous body do not change during such a short time. The higher OSI means the greater scattering of light and the lower optical quality.^[17] We found a significantly increased average tear film OSI and Δ OSI/time in the short TBUT group compared to the normal group. Any factor that affects the stability of the tears can cause increased light scattered in the anterior surface of the cornea, affecting the tear film OSI. Previous researches had confirmed that short TBUT patients show an irregular tear film distribution across the cornea.^[11,12] Huang et al^[18] showed that the surface regularity index and the surface asymmetry index were significantly improved by instilling artificial tears in dry eye participants. The nonhomogeneity of the tear film could distort reflections from the air-tear film interface. However, tear film changes also affect intraocular scatter and dispersion as the tear film is the first refractive medium that the light enters in the eye. Szczesna-Iskanders^[19] evaluated tear film dynamics in terms of its post-blink leveling, and found that dry eye subjects showed earlier leveling of the tear film than normal eyes. The difference may be because, in part, of the changes of polar and nonpolar content of the lipid layer. The tear lipid composition could affect the light pathway and lead to the increase of tear film OSI. Losing of goblet cells which secrete gel-forming mucins is a hallmark of dry eye disease. Mucins are large and complex heavily glycosylated proteins, which are secreted by goblet cells and play an important role in protecting the integrity of the ocular surface.

In our study, the tear film OSI shows a rising curve in the short TBUT group. Whereas in the control group, the tear film OSI curve shows an upward trend in the first second, then the curve tends to be relatively flat at approximately 2 to 5 seconds. After 5 seconds, the curve shows a rising trend. The difference of the OSI curve may be because of the tear film dynamic change. Also, previous studies found that the osmolarity was increased in dry eye patient. The changed osmolarity of the tear film may affect the scattering of light to some extent. In the short TBUT patients, the tear film dynamics become abnormal just at the time after blink. Therefore, the curve has always shown an upward trend. Under normal circumstances, the tear film is constantly changing and the TBUT is a dynamic process. It undergoes a formation phase immediately after eye blink and a subsequent deformation. According to the OSI curve of the normal group in our study, it takes an average of 1 second for the tear film to build up.

Dry eye participants usually complain of eye discomfort and blurred vision. Previous studies^[12–15,20–23] have reported visual disturbance, reduced optical quality, and even degraded quality of vision. In this study, we detected a significantly reduced MTF and SR in short TBUT patients compared to the control subjects.

This means that the stability of the tear film plays an important role in the optical quality of the eye. A sequential downward curve in the MTF could be observed in the short TBUT group after a complete blink. But in the control group, the curve is relatively flat at approximately 1 to 6 seconds. This difference may be because of the abnormal dynamic change in short TBUT eyes. Also, unstable tear film could create aberrations, and these cause a reduction in optical quality. One study^[10] reported that the cornea-tear film would cause significantly increased wavefront aberrations in normal subjects if interblink periods exceeded 10 seconds. This result was similar to our finding that the mean value of MTF was significantly decreased at 10 seconds rather than at 1 second in normal participants. After 6 seconds, the MTF curve starts to reduce in the control subjects. However, under normal conditions, the normal blink intervals are approximately 6 seconds. So, for most of the normal subjects, eye blink could happen before the MTF start to reduce.

To summarize, the changes of the tear film in short TBUT participants reduced optical qualities compared with those in normal eyes. Dry eye participants present different tear film OSI and MTF curves. It is essential to improve tear film stability to obtain normal optical quality.

Author contributions

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Formal analysis: Lei Xi, Jiayin Qin.

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Project administration: Yongzhen Bao.

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Writing – original draft: Lei Xi.

Writing – review & editing: Lei Xi, Jiayin Qin, Yongzhen Bao.

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