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Research article

# Comparison of the different operation room environmental exposures on tear film function before and after operation

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ABSTRACT

1.2 Previous studies have confirmed that air and light pollution can cause damage to a number of systems throughout the body, including the ocular surface and retina. However, the exact effect of air pollution and light pollution on tear film function is not clear. This study explored the different operation room environmental exposures on tear film function before and after operation. Sixty medical staff in the operating room were selected and divided into 4 groups according to different surgical methods to evaluate the tear film function before and after operation: Da Vinci surgery group (DVSS), Laparoscopic surgery group (LS), Traditional surgery group (TS), and Ophthalmic microsurgery group (OM). The results showed that the levels of light and air pollution were elevated in operating rooms during the operation and the changes of tear film function in the other three groups were statistically significant except for DVSS group. In TS group, particulate matter (pm) 1 ($R = 0.61$, $p < 0.01$), pm2.5 ($R = 0.63$, $p < 0.01$), and pm10 ($R = 0.67$, $p < 0.01$) were positively correlated with eye redness index, and first and average noninvasive tear film break-up times were positively correlated with illuminance ($R = 0.54$, $p < 0.05$; $R = 0.97$, $p < 0.01$). In OM group, there was a positive correlation between the operation time and the first ($R = 0.69$, $p < 0.01$) and average ($R = 0.89$, $p < 0.01$) noninvasive tear film break-up times. Our research found that exposure to different operating room environment will lead to damage of tear film function, but also provide a theoretical basis for the improvement of surgical environment.

## 1. Introduction

Dry eye is a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film and accompanied by ocular symptoms [1]. Air pollution and light pollution are among the risk factors for dry eye disease. Air pollution includes particulate matter (pm) 1, pm2.5, pm10, $NO_2$, $O_3$, $SO_2$, total volatile organic compounds (TVOC), and formaldehyde (HCHO), among which pm2.5, $NO_2$, and $O_3$ have been shown to play a role in the development of allergic conjunctivitis [2], and it has also been shown that pm2.5 causes a decrease in the number and disorganization of corneal and conjunctival epithelium in mice, which accelerates the development of dry eye [3]. Light pollution also leads to a decrease in tear meniscus height, a decrease in the time to first tear film break-up, a decrease in the mean tear film break-up time, and an increase in the ocular redness index [4]; long-term exposure to light

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pollution also causes damage to the physiological structure of the retina and promotes cell death [5,6].

The emergence of electric knives, ultrasonic knives, microscopes, shadowless lamps and other devices is like a double-edged sword, greatly promoting the development of modern surgical technology but also bringing many problems, such as air pollution and light pollution. Some data show that the use of electrosurgical equipment during surgery can generate pm2.5 values up to 303.10 ± 108.95 μg/m$^3$ [7],which is more than ten times the normal value, and the general operating room shadowless lamp illuminance can also be 30, 000–50,000 lux, which is approximately 60~100 times the illuminance of comfortable reading (500 lux) [8].

However, many doctors and nurses are exposed to the operating room environment for a long time. Studies have shown that air and light pollution can cause damage to multiple systems throughout the body [9], including the ocular surface [10,11].Light pollution can also cause damage to retinal cells [12], but there is uncertainty regarding the effect of the operating room environment on tear film function. Therefore, we focused on the different operation room environmental exposures on tear film function before and after operation.

## 2. Method

### 2.1. Environmental data measurement

Environmental data were obtained from the operating room of the First Affiliated Hospital of Xi'an Jiaotong University from February 2022 to April 2022. Air levels of pm1, pm2.5, pm10, TVOC and HCHO were measured using SENSOLOGY's MEF-550 integrated air detector, parallel to the staff's head and face, directly above the surgical field until a peak occurred; illuminance in the surgical area was measured using DELIXI's DLY-1802 illuminance meter.

### 2.2. Subjects and groups

This study was approved by the institutional review committee of the First Affiliated Hospital of Xi'an Jiaotong University, the Approval number is XJTU1AFCRC2018SJ-014. Informed consent was obtained from each subject for all examinations and procedures. Sixty staff members from the operating room of the First Affiliated Hospital of Xi'an Jiaotong University from March 2022 to April 2022 were randomly selected, and the eye with more symptom were selected for each object. Then the selected eyes were divided into four groups according to different surgical methods: DVSS, LS, TS, and OM. These staff members are representative of those who have been in the operating room environment for an extended period of time. Study objects had to meet the following inclusion criteria: (a) be aged 18–65 years old, no restriction on gender. (b) working long hours per day in the operating room, including instrument nurses and physicians involved in surgery; (c) good compliance, can complete the examination within 30 min after the end of the procedure. Study objects were excluded if they met any of the following exclusion criteria: (a) had experienced ocular surface inflammation or ocular trauma; (b) were being treated with steroidal and non-steroidal anti-inflammatory drugs and immunosuppressants; (c) had participated in other medical device trials or drug clinical trials within the last 3 months; (d) Poor compliance and inability to complete post-operative examinations in a timely manner.

### 2.3. Evaluation indicators and sampling methods

A noninvasive keratograph 5 M ocular surface analyzer (OCULUS, Germany) was used to standardize the ocular surface condition of the study subjects to obtain the relevant indices, and no eye drops or eye surface contact were used or performed 1 h before the test. All study object examinations and measurements were performed by the same ophthalmologist with standardized training and experience in the same environment. Study objects were instructed to place their jaws on the jaw rest, look straight ahead, focus clearly with infrared light, move their eyes 3 times and then not blink until the end of each item measurement, and rest for 1 min with eyes closed after each item before proceeding to the next test mode to obtain the following indices: (a) noninvasive keratograph tear meniscus height (NIKTMH): measured by taking a clear image of the tear meniscus and using a built-in scale; (b) noninvasive tear film break-up time (NIBUT): NIBUT includes noninvasive first tear break-up time (NIBUT-first) and noninvasive average tear break-up time (NIBUT-average). The program automatically records the duration of the process and derives the first tear film break-up time and the average tear film break-up time(s), i.e., NIBUT-first and NIBUT-average; (c) ocular redness index analysis: the automatic activity score index (0–4 points) according to ocular surface congestion in the clear state of the focal conjunctival vessels, representing the severity of the presence of ocular surface congestion, with a larger score indicating a more severe degree of congestion. All data collection was performed by the same person. The preoperative and postoperative tear meniscus heights, first and average tear film break-up times, and ocular redness index were collected separately, and the duration of surgery was also recorded.

The Ocular Surface Disease Index (OSDI) dry eye questionnaire was used to assess the subjective ocular discomfort of the OR staff during the past week [13],and the Visual Analogue Scale (VAS) record table was used to assess their preoperative and postoperative subjective ocular discomfort and other signs [14]. Subjects were asked to draw a vertical line on a horizontal line and rate each ocular symptom (including burning sensation, pruritus, foreign body sensation, blur vision, sears optical, photophobia and pain) due to dry eyes on a scale of discomfort. 0 % corresponds to no discomfort and 100 % indicates highest level of discomfort.

### 2.4. Statistical analysis

SPSS Statistic 25 from International Business Machine (IBM) in the USA was used for statistical analysis. Data were expressed as the mean ± standard deviation or median (quartile range). A paired test was used to compare the significant preoperative and postoperative differences in various indices of the ocular surface, and Spearman's correlation was used to evaluate the correlation between air pollutants, illuminance, duration of operation and changes in ocular signs ($P < 0.05$). All tests were bilateral.

## 3. Result

### 3.1. Demographic data

Sixty subjects were enrolled in this study, including 32 males (53.33 %) and 28 females (46.47 %). Slightly more than half of the subjects were ≥30 years old (35, 58.33 %), and a small number of subjects were less than 30 years old (25, 41.62 %). A total of 39 (65 %) people had mild to severe ocular discomfort according to the OSDI score; 18 (30 %) were rated as having mild dry eye (13–22 points), 14 (23.33 %) were rated as having moderate dry eye (23–32 points), and 7 (11.67 %) were rated as having severe dry eye (>32 points), with the highest OSDI score of 19.64 ± 12.33 in the TS group and the lowest score of 11.26 ± 9.15 in the OM group (Table 1).

### 3.2. Postoperative VAS score was significantly increased

In this study, the total VAS score was used to assess the severity of eye discomfort. The total VAS score was significantly increased from preoperative to postoperative scores. Among the four groups, the largest increased in total VAS score occurred in the DVSS group. Sears Optical exhibited the greatest increased in VAS score, followed by foreign body sensation (Table 2).

### 3.3. Preoperative and postoperative differences in tear film function index

There was no statistical difference in the length of surgery and the specific surgical procedure within the group. In this study, NIKTMH (excluding the DVSS group), NIBUT-first, NIBUT-average and redness of all four groups showed a marked change between the preoperative and postoperative results (Fig. 1).

### 3.4. Comparison of operating room environments and operation-time in the four groups

The illuminance was measured within the field of view of the screen in the DVSS and LS groups, the shadowless lamp in the TS group, and the microscope in the OM group. Among them, the illuminance measured by TS group was significantly different from that of the other three groups (Fig. 2). In the measurement of air pollutants, no harmful substances were measured because the surgical smoke generated in the DVSS and LS groups was discharged directly from the abdominal cavity through the ducts, and no harmful substances were measured in the OM group because no electrosurgical equipment was used. (Table 3). The OM group was significantly different from the other three groups in operation-time (Fig. 3).

### 3.5. Relationship between environmental indicators and tear film function

Tables 4–7 show the degree of correlation between the preoperative and postoperative changes in tear film function and environmental indicators, expressed by the correlation coefficient R.

#### 3.5.1. The Da Vinci surgery group

In this study, no harmful pollutants were detected in indoor air in the DVSS group, and there was a positive correlation between operation time and OSDI score ($R = 0.71$, $p < 0.05$) (Table 4).

#### 3.5.2. The traditional surgery group

Air and light pollution were correlated with tear film function and ocular surface changes in the TS group (Table 5).

In the TS group, the first ($R = 0.54$, $p < 0.05$) and average ($R = 0.97$, $p < 0.01$) tear film break-up times were positively correlated with illuminance. pm1($R = 0.61$, $p < 0.01$), pm2.5($R = 0.63$, $p < 0.01$), and pm10($R = 0.67$, $p < 0.01$) were positively correlated with the ocular redness index.

**Table 1**
The sex, age and OSDI of the four groups.

| | Gender(n%) | | Age(n%) | | OSDI |
|---|---|---|---|---|---|
| | Male | Female | <30 years | ≥30 years | |
| DVSS (n = 10) | 5(50) | 5(50) | 5(50) | 5(50) | 17.35 ± 10.43 |
| LS(n = 19) | 12(63.16) | 7(36.84) | 6(31.58) | 13(68.42) | 14.06 ± 10.62 |
| TS(n = 18) | 12(66.67) | 6(33.3) | 4(22.22) | 14(77.78) | 19.64 ± 12.33 |
| OM(n = 13) | 3(23.08) | 10(76.92) | 10(76.92) | 3(23.08) | 11.26 ± 9.15 |
| Total(n = 60) | 32(53.33) | 28(46.67) | 25(41.67) | 35(58.33 ) | 18.77 ± 13.14 |

DVSS, da Vinci surgical system; LS, laparoscopic surgery; TS, traditional surgery; OM, ophthalmic microsurgery. OSDI, Ocular Surface Disease Index.

**Table 2**
VAS preoperative and postoperative scores.

| | DVSS | | | LS | | | TS | | | OM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre | post | p-Value | pre | post | p-Value | pre | post | p-Value | Pre | post | p-Value |
| Total | 0(0,3.65) | 13.85(6.17,21.77) | 0.00 | 0(0,1.80) | 8.40(5.50,15.00) | 0.00 | 0(0,1.32) | 6.25(2.90,10.62) | 0.00 | 0(0,0) | 6.30(3.35,11.70) | 0.00 |
| Burning sensation | 0(0,0.18) | 0.50(0,3.28) | 0.04 | 0(0,0) | 0.20(0,1.20) | 0.03 | 0(0,0.08) | 0(0,1.12) | 0.02 | 0(0,0) | 0.10(0,0.80) | 0.02 |
| Pruritus | 0(0,0.30) | 1.35(0,4.22) | 0.02 | 0(0,0) | 0.70(0,1.90) | 0.03 | 0(0,0.05) | 0.50(0,1.35) | 0.00 | 0(0,0) | 0(0,0.35) | 0.07 |
| Foreign Body Sensation | 0(0,0.28) | 1.45(0.22,3.12) | 0.01 | 0(0,0.30) | 1.10(0.10,3.10) | 0.01 | 0(0,0) | 1.55(0,3.38) | 0.00 | 0(0,0) | 1.40(0.25,2.00) | 0.01 |
| Blur Vision | 0(0,0) | 1.35(0,3.62) | 0.03 | 0(0,0) | 0.80(0,3.00) | 0.10 | 0(0,0.15) | 1.35(0,2.72) | 0.00 | 0(0,0) | 0(0,0.95) | 0.04 |
| Sears Optical | 0(0,1.48) | 3.45(0,5.00) | 0.04 | 0(0,0.30) | 2.50(1.80,5.40) | 0.00 | 0(0,0.48) | 2.45(1.30,3.92) | 0.00 | 0(0,0) | 3.40(2.00,5.05) | 0.00 |
| Photophobia | 00,0.32) | 1.35(0,4.65) | 0.03 | 0(0,0) | 1.10(0,2.30) | 0.00 | 0(0,0) | 0(0,2.48) | 0.01 | 0(0,0) | 0(0,1.10) | 0.03 |
| Pain | 0(0,0.02) | 0.05(0,1.42) | 0.04 | 0(0,0) | 0.30(0.30,0.60) | 0.00 | 0(0,0) | 0(0,0.62) | 0.02 | 0(0,0) | 0.10(0,0.20) | 0.02 |

Data are expressed as quartiles. DVSS, da Vinci surgical system; LS, laparoscopic surgery; TS, traditional surgery; OM, ophthalmic microsurgery.

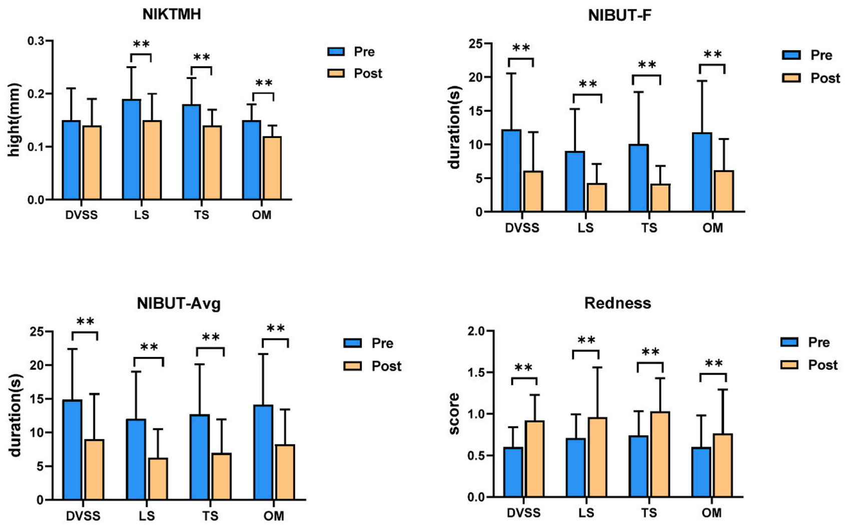


**Fig. 1.** Changes in tear film function in the four groups
Fig. 1 Effects of different surgical methods on NIKTMH, redness, NIBUT-F and NIBUT-Avg. Data presented as the mean and standard deviation. **P ≤ 0.01. NIKTMH, noninvasive keratograph tear meniscus height; NIBUT-F, first noninvasive tear film break-up time; NIBUT-Avg, average noninvasive tear film break-up time; DVSS, da Vinci surgical system; LS, laparoscopic surgery; TS, traditional surgery; OM, ophthalmic microsurgery.

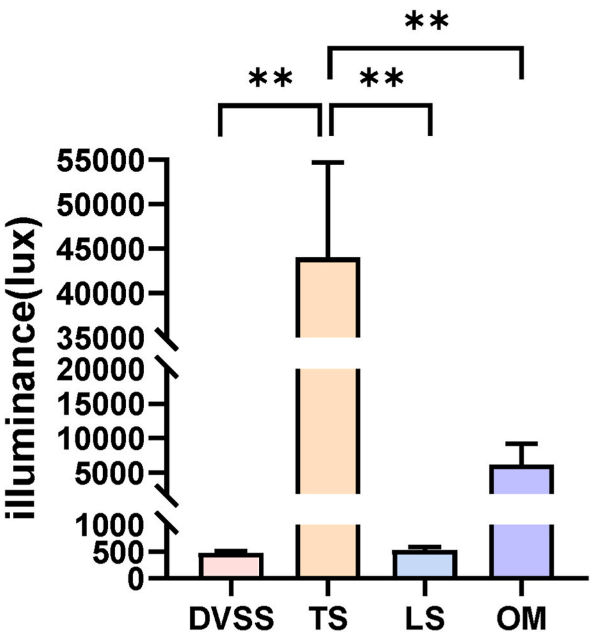


**Fig. 2.** Comparison of illuminance among the four groups
Fig. 2 The illuminance measured by TS group was significantly different from that of the other three groups. Data presented as the mean and standard deviation. **P ≤ 0.01. DVSS, da Vinci surgical system; TS, traditional surgery; LS, laparoscopic surgery; OM, ophthalmic microsurgery.

### *3.5.3. The laparoscopic surgery group*

No harmful pollutants were detected in indoor air in the LS group. A relationship between environmental factors and tear film function was not found (Table 6).

### *3.5.4. The ophthalmic microsurgery group*

In the OM group, there was a positive correlation between the operation time and the difference in the first noninvasive tear film break-up time ($R = 0.69$, $p < 0.01$) and the average tear film break-up time ($R = 0.89$, $p < 0.01$) (Table 7).

**Table 3**
Comparison of environmental parameters among different surgery type.

| | Operation-Time(h) | illuminance(lux) | pm1(ug/m$^3$) | pm2.5(ug/m$^3$) | pm10(ug/m$^3$) | TVOC (mg/m$^3$) | HCHO (mg/m$^3$) |
|---|---|---|---|---|---|---|---|
| DVSS | 5.50 ± 1.78 | 473.80 ± 42.22 | – | – | – | – | – |
| LS | 5.85 ± 2.51 | 525.30 ± 75.98 | – | – | – | – | – |
| TS | 6.20 ± 2.86 | 47505.55 ± 11694.67 | 678.00 ± 148.03 | 742.94 ± 156.76 | 815.77 ± 171.53 | 4.02 ± 2.74 | 2.18 ± 0.53 |
| OM | 2.80 ± 1.03 | 5927.00 ± 2972.84 | – | – | – | – | – |

DVSS, da Vinci surgical system; LS, laparoscopic surgery; TS, traditional surgery; OM, ophthalmic microsurgery; pm, particulate matter; TVOC, total volatile organic compounds; "-", not detected.

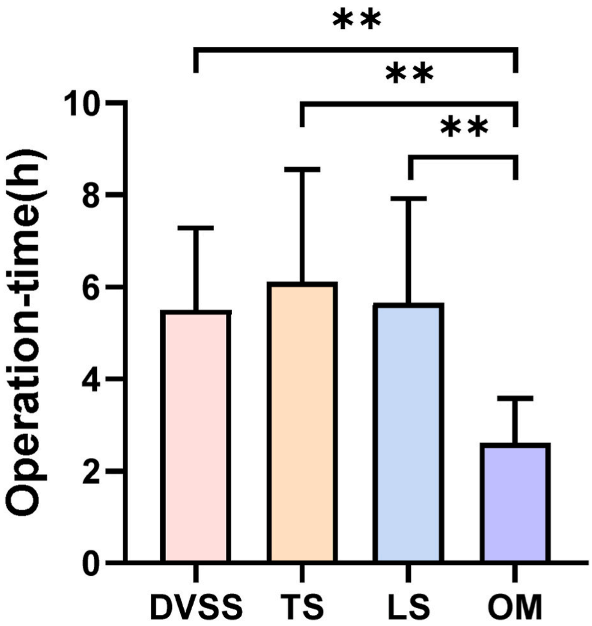


**Fig. 3.** Comparison of operation-time among the four groups
Fig. 3 The operation-time measured by OM group was significantly different from that of the other three groups. Data presented as the mean and standard deviation. **P ≤ 0.01. DVSS, da Vinci surgical system; TS, traditional surgery; LS, laparoscopic surgery; OM, ophthalmic microsurgery.

**Table 4**
Correlation between environmental and ocular surface sign changes in the DVSS group.

| | NIKTMH | NIBUT-First | NIBUT-Average | Redness | OSDI |
|---|---|---|---|---|---|
| Operation-Time | 0.24 | 0.28 | −0.08 | −0.4 | 0.71[a] |
| illuminance | 0.22 | −0.14 | −0.22 | 0.07 | 0.62 |

NIKTMH, noninvasive keratograph tear meniscus height; NIBUT, noninvasive tear film break-up time; OSDI, Ocular Surface Disease Index.
[a] Correlation is significant at the 0.05 level (2-tailed).

## 4. Discussion

In 1996, the United States (the Association of Perioperative Registered Nurses (AORN)) became aware of the dangers of surgical smoke and began to address the range of problems it posed [15]. The smoke produced by using electrosurgical equipment for 15 min is equivalent to the damage caused by 60 cigarettes. Surgical smoke contains more than 600 chemical components, including several dangerous and potentially carcinogenic chemicals [16,17]. In addition to the hazards mentioned above, our findings also show that in the TS group, the pm2.5 from the use of electrosurgical equipment could be as high as 742.94 ± 156.7 μg/m$^3$, a value ten times higher than the national standard. The values of TVOC and HCHO were also several times higher than the national standard. The air pollution indicators in the operating room measured in this study were higher than those in previous studies [7], and these differences may be due to differences in methodology. In our study, 39 of the 60 study subjects (65 %) had varying degrees of dry eye symptoms, which is higher than the 5–50 % seen in the normal population [18]. The total VAS score in the TS group increased after surgery, and the OSDI score of 21.31 ± 17.90 in the TS surgical group was the highest among the four groups. This could be related to air pollution and/or excessive light levels in the operating room. We suggest that uncomfortable ocular surface symptoms may be related to severe air

**Table 5**
Correlation between environmental and ocular surface sign changes in the TS group.

| | NIKTMH | NIBUT-First | NIBUT-Average | Redness | OSDI |
|---|---|---|---|---|---|
| Operation-Time | −0.19 | 0.02 | −0.35 | 0.37 | 0.16 |
| illuminance | 0.20 | 0.54[a] | 0.97[b] | −0.05 | −0.38 |
| pm1 | 0.17 | 0.13 | 0.24 | 0.61[b] | −0.44 |
| pm2.5 | 0.15 | 0.11 | 0.17 | 0.63[b] | −0.42 |
| pm10 | 0.15 | 0.07 | 0.13 | 0.67[b] | −0.41 |
| TVOC | 0.26 | 0.12 | 0.25 | 0.10 | 0.10 |
| HCHO | 0.31 | −0.40 | −0.05 | 0.36 | −0.01 |

NIKTMH, noninvasive keratograph tear meniscus height; NIBUT, noninvasive tear film break-up time; OSDI, Ocular Surface Disease Index; PM, particulate matter; TVOC, total volatile organic compounds.
[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

**Table 6**
Correlation between environmental and ocular surface sign changes in the LS group.

| | NIKTMH | NIBUT-First | NIBUT-Average | Redness | OSDI |
|---|---|---|---|---|---|
| Operation-Time | −0.18 | 0.14 | 0.06 | −0.15 | 0.14 |
| illuminance | −0.22 | −0.10 | −0.06 | 0.26 | −0.18 |

NIKTMH, noninvasive keratograph tear meniscus height; NIBUT, noninvasive tear film break-up time; OSDI, Ocular Surface Disease Index.
Correlation is significant at the 0.01 level (2-tailed).

**Table 7**
Correlation between environmental and ocular surface sign changes in the OM group.

| | NIKTMH | NIBUT-First | NIBUT-Average | Redness | ODSI |
|---|---|---|---|---|---|
| Operation-Time | −0.24 | 0.69[a] | 0.89[a] | 0.00 | −0.51 |
| Illuminance | 0.21 | 0.01 | 0.21 | 0.12 | −0.41 |

NIKTMH, noninvasive keratograph tear meniscus height; NIBUT, noninvasive tear film break-up time; OSDI, Ocular Surface Disease Index.
[a] Correlation is significant at the 0.01 level (2-tailed).

pollution.

A similar published article suggested that air pollution may lead to instability of the tear film, which can trigger dry eye [19,20]. In our study, different levels of light and air pollution in the operating room were detected in different surgery groups. There were statistically significant differences in the postoperative changes in tear meniscus height, noninvasive first and average tear film break-up times, and ocular redness index compared to the preoperative period in all groups, except for the DVSS group, where there was no significant difference in the change in tear meniscus height before and after surgery. In the TS group, the ocular redness index was moderately correlated with the air pollution indices pm1 ($p < 0.01$, $R = 0.61$), pm2.5 ($p < 0.01$, $R = 0.631$), and pm10 ($p < 0.01$, $R = 0.67$). Therefore, it can be inferred that air pollution is negatively correlated with the stability of tear film function. The training and education of operating room staff to raise awareness of the hazards of air pollution is important; on the other hand, hospital managers should monitor the relevant air pollution indicators in the operating room and improve the smoke extraction system in the operating room to provide better protection for medical and nursing staff.

In addition to air pollution, light pollution has been shown to cause some damage to our eyes. In addition to the effects of excess light on the retina causing apoptosis of retinal photoreceptor cells, the influence of light pollution on the ocular surface should be studied [17,21–23]. However, the effects on the tear film function are relatively rare. Our results showed that the illuminance of the surgical area measured in the TS group was $47505.55 \pm 11694.67$ lux, which was approximately 47–118 times higher than normal reading illuminance (500 lux). In the TS group, the highest OSDI score was found, and the change in first ($p < 0.05$, $R = 0.545$) and average ($p < 0.01$, $R = 0.973$) tear film break-up times preoperatively and postoperatively correlated with the light intensity in the operating room. In the OM group, the illumination level of the surgical area was $5927.00 \pm 2972.84$ lux, approximately 6–17 times the normal reading illumination level, and the first ($p < 0.01$, $R = 0.692$) and average ($p < 0.01$, $R = 0.545$) tear film break-up times showed a correlation with the duration of surgery. Under a microscope, the operative area is more confined, which may be one reason for a correlation between the time of surgery and tear film break-up. Lee HS et al. showed that overexposure to short wavelengths of visible light can increase inflammatory markers and oxidative stress and induce apoptosis, which may exacerbate clinical dry eye parameters in mice [24].

The results ( Table 4 &Table 6 ) showed that there was no significant correlation between environmental factors and tear film function in DVSS group (except OSDI) and LS group. we could consider that the environment of the two groups is similar to the illuminance and air quality of daily life and bigger sample size are needed to repeat the study to obtain more reliable results; In addition, the difference of the relation between the operation-time and OSDI in the DVSS group and LS group (although similar environment in the two group), we guess that the distance between the eyes and the screen might be responsible for this difference.

However, this study also has some limitations: (I)This is a single-center study with a relatively limited sample size; (II)the environmental monitoring indicators used are maximum values, and further research is needed on the dynamics of air pollution indicators during surgery.

In summary, our findings suggest that different operation room environmental exposures can affect tear film function before and after operation. Inventing better surgical equipment and optimizing the operation environment will be valuable for protecting operation staff.

## Data availability statement

Data will be made available on request.


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## Ethics approval and consent to participate

This study was approved by the institutional review committee of the First Affiliated Hospital of Xi'an Jiaotong University, the Approval number is XJTU1AFCRC2018SJ-014. Informed consent was obtained from each subject for all examinations and procedures.

## CRediT authorship contribution statement

**Yufei Dang:** Writing – original draft, Visualization, Software, Investigation, Formal analysis. **Ming Zhang:** Methodology, Data curation. **Yanqiang Wei:** Project administration. **Na Duan:** Resources. **Linjuan Zhang:** Project administration. **Rujia Liu:** Investigation. **Zhen Zhang:** Validation. **Yue Zhang:** Methodology. **Li Li:** Writing – review & editing, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.


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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24530.

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