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*Original Article*

# Efficacy of moisture chamber goggles combined with fluorometholone eye drops on visual function and oxidative stress in patients with dry eye disease

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**Abstract:** Objective: To evaluate the effects of Moisture Chamber Goggles combined with Fluorometholone eye drops on visual function and oxidative stress in patients with dry eye disease. Methods: A retrospective analysis was conducted on 80 patients with dry eye disease treated at Ninghai First Hospital from January 2021 to May 2023. Patients were divided into a combination group (n=40, receiving Fluorometholone eye drops and Moisture Chamber Goggles) and a monotherapy group (n=40, receiving Fluorometholone eye drops alone) based on treatment regimens. Outcomes compared between the groups included subjective symptom scores (VAS), tear film stability parameters, inflammatory markers, oxidative stress indicators, and adverse reaction rates before and after treatment. Results: Post-treatment, the combination group showed significantly longer tear breakup time (BUT) and higher Schirmer's test values compared to the monotherapy group (both $P<0.05$). Levels of tumor necrosis factor-α and metalloproteinase-2 were significantly lower in the combination group ($P<0.05$). Additionally, the combination group had significantly lower VAS scores, Ocular Surface Disease Index (OSDI) scores, and conjunctival hyperemia grades, as well as higher tear meniscus height and National Eye Institute Visual Function Questionnaire (VFQ-25) scores (all $P<0.05$). No significant differences in the incidence of adverse reactions were observed between the two groups ($P>0.05$). Conclusion: The combination of Moisture Chamber Goggles and Fluorometholone eye drops significantly improves subjective visual quality, promotes tear secretion, stabilizes the tear film, and reduces inflammatory and oxidative stress markers in patients with dry eye disease, while maintaining a favorable safety profile.

**Keywords:** Moisture chamber goggles, fluorometholone, visual function, tear film stability, inflammatory markers, oxidative stress, treatment safety

## Introduction

Dry eye disease, also known as keratoconjunctival dryness, is one of the most common conditions in ophthalmology. It encompasses a group of disorders characterized by abnormalities in the quality, quantity, or kinetics of tear fluid, leading to tear film instability and ocular surface abnormalities. Patients often report symptoms of ocular discomfort, such as dryness, foreign body sensation, and visual fatigue [1, 2]. In 1995, Brewitt defined dry eye as an ocular surface disease caused by tear film instability due to impaired natural functions and protective mechanisms of the external eye [3]. The typical clinical manifestations of dry eye include ocular dryness, visual fatigue, foreign body sensation, and photophobia. While mild cases may reduce quality of life and daily functioning, severe cases can lead to corneal keratinization or even perforation [4]. In recent years, lifestyle changes driven by rapid economic development have led to increased screen time from computers, televisions, and gaming devices, contributing to a rise in the incidence of dry eye disease, particularly in younger populations [5, 6].

Current treatment options for dry eye include pharmacological, surgical, and physical therapies. Surgical interventions, while effective for severe cases, carry inherent risks and are not widely applicable. Pharmacological treatments are cost-effective and widely accessible but often have limited long-term efficacy and notable side effects. Physical therapies have gained

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**Table 1.** Comparison of baseline clinical data ($\bar{x}$±s)/[n (%)]

| General clinical information | | Combination group (n=40) | Monotherapy group (n=40) | $t/\chi^2$ | *P* |
|---|---|---|---|---|---|
| Gender | Male | 26 (65.00) | 20 (50.00) | 1.841 | 0.175 |
| | Female | 14 (35.00) | 20 (50.00) | | |
| Mean age (years) | | 47.38±11.12 | 46.55±15.97 | 0.270 | 0.788 |
| Mean duration of disease (months) | | 18.63±8.78 | 18.80±7.23 | 0.095 | 0.925 |

**Table 2.** Comparison of visual analog scale scores for subjective symptoms between the two groups before and after treatment

| Group | Number | Before treatment | After treatment | *t* | *P* |
|---|---|---|---|---|---|
| Combination group | 40 | 5.73±1.69 | 2.38±1.55 | 9.239 | 0.000 |
| Monotherapy group | 40 | 5.98±1.03 | 3.05±1.78 | 9.011 | 0.000 |
| *t* | - | 0.798 | 1.795 | - | - |
| *P* | - | 0.427 | 0.076 | - | - |

clinical attention due to their targeted action on periocular tissues and reduced risk of systemic side effects [7, 8].

Moisture Chamber Goggles, comprising components like lens legs and anti-fog lenses, create a ventilated and humid microenvironment around the eyes to maintain hydration and alleviate dryness [9, 10]. While Fluorometholone eye drops have been widely studied and shown to be effective in managing dry eye disease [10], the combined use of Fluorometholone eye drops with Moisture Chamber Goggles remains underexplored. This study retrospectively analyzes the efficacy of Moisture Chamber Goggles combined with Fluorometholone eye drops on visual function and oxidative stress in patients with dry eye disease.

## Materials and methods

### *Study design and patient selection*

This retrospective cohort study was approved by the Ethics Committee of Ninghai First Hospital. Patient records from January 2021 to May 2023 were retrieved from the hospital's electronic medical record system. An initial pool of 109 patients diagnosed with dry eye disease was identified, followed by a secondary screening based on specific inclusion and exclusion criteria.

Inclusion criteria: (1) Patients met the diagnostic criteria of the internationally recognized Ocular Surface Disease Index (OSDI) scale [11] and exhibited relevant clinical symptoms. (2) Patients were aged 18 years or older. (3) Patients had comprehensive baseline clinical data, including demographics (gender, age), disease duration, OSDI scores (pre- and post-treatment) [12], and relevant laboratory results [e.g., tumor necrosis factor-α (TNF-α) levels, tear film stability indicators]. (4) Patients received treatment with either Moisture Chamber Goggles combined with Fluorometholone eye drops or Fluorometholone alone. Exclusion criteria: (1) Patients with psychiatric disorders. (2) Patients lacking essential assessment indicators. (3) Patients with incomplete follow-up data.

After secondary screening, 80 patients met the criteria and were included in the study. These patients were grouped according to their treatment plans: Combination group (n=40): Patients received Moisture Chamber Goggles combined with Fluorometholone eye drops under medical supervision. Monotherapy group (n=40): Patients received Fluorometholone eye drops alone under medical supervision.

### *Data collection*

Baseline Data: Gender, age, and disease duration were recorded. Subjective Symptoms: Visual analog scale (VAS) scores for subjective symptoms were assessed before treatment and at 2 months post-treatment. Scores ranged from 0 (no abnormal sensation) to 10 (severe symptoms, including blurred vision, fatigue, and a pronounced foreign body sensation).

Tear film stability indicators: Break-Up Time (BUT): Measured as follows [13]: After blinking

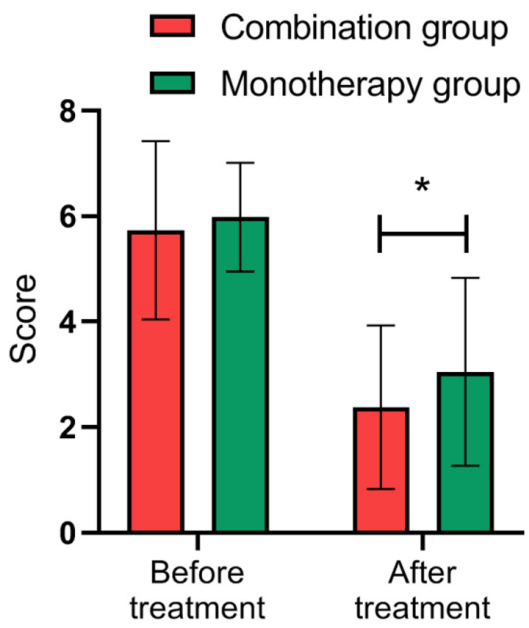


**Figure 1.** The differences in VAS scores for subjective symptoms before and after treatment between the two groups of patients. There was no statistically significant difference in VAS scores for subjective symptoms between the two groups before treatment ($P>0.05$). After treatment, the VAS scores in the combination group were significantly lower than those in the monotherapy group ($P<0.05$). * indicates a statistically significant difference between the groups. VAS: visual analog scale.

several times, patients were instructed to look straight ahead. The time to the first tear film rupture was recorded using a slit lamp microscope. This process was repeated three times, and the average value was taken as the final data. Schirmer I Test (SIt): Conducted as follows [14]: A sterile test strip was placed in the outer one-third of the patient's lower conjunctival sac. Patients were instructed to look straight ahead and close their eyes. After 5 minutes, the length of tear film wetting on the test strip was measured.

Inflammatory and Oxidative Stress Markers: Levels of tumor necrosis factor-α (TNF-α) and matrix metalloproteinase-2 (MMP-2) were evaluated before treatment and at 2 months post-treatment. Blood samples were collected, centrifuged, and analyzed using enzyme-linked immunosorbent assay (ELISA) kits purchased from Thermo Fisher Scientific.

Ocular surface indicators: OSDI Score: Ranged from 0 to 100, with higher scores indicating more severe symptoms. Conjunctival Hyperemia: Graded on a scale from 1 to 4, with higher grades reflecting more severe hyperemia. Tear Meniscus Height (TMH): Measured using images of the eyelid tear meniscus captured by an ophthalmic camera.

Quality of Life: The National Eye Institute Visual Function Questionnaire (NEI-VFQ-25) assessed general health and vision, difficulty with activities, and responses to vision problems. The total score ranged from 0 to 100, with higher scores indicating better quality of life.

Adverse Reactions: Incidence of adverse reactions, such as eye irritation, was monitored over the 2-month treatment period.

*Follow-up endpoints*

The follow-up endpoint was defined as the completion of the treatment for the last patient in May 2023, concluding in July 2023 after the 2-month treatment period.

*Quality control*

To ensure data accuracy, all data collection and entry were conducted by two trained individuals familiar with the study's background and processes.

*Statistical methods*

Data were processed using Excel 2021 and analyzed with the Statistical Package for the Social Sciences (SPSS) version 21.0. Measurement data, such as age and disease duration, conforming to a normal distribution, were expressed as mean ± standard deviation and analyzed using t-tests. Categorical data were presented as rates and analyzed with the chi-square test. Statistical significance was defined as $P<0.05$.

## Results

*Comparison of baseline clinical data*

Baseline clinical characteristics, including gender, age, and disease duration, were collected for both groups via the hospital information system. Comparative analysis showed no statistically significant differences between the two groups (all $P>0.05$), confirming their comparability. See **Table 1**.

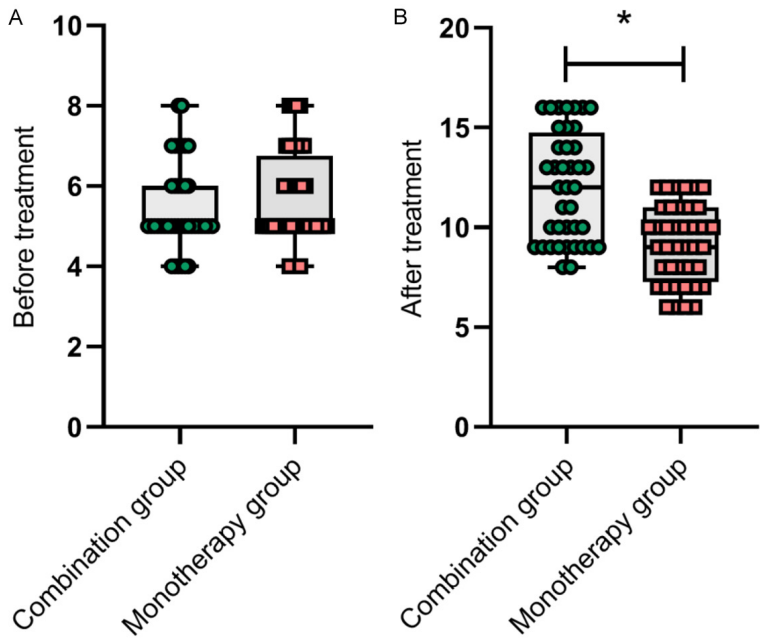


**Figure 2.** Comparison of BUT indicator between the two groups before and after treatment. The pre-treatment BUT levels did not differ significantly between the groups (*P*>0.05), while the post-treatment BUT levels in the combination group were significantly higher than in the monotherapy group (*P*<0.05). * indicates a statistically significant difference between the groups. BUT: break-up time.

*Comparison of VAS scores for subjective symptoms*

Before treatment, there was no significant difference in VAS scores for subjective symptoms between the groups (P>0.05). Post-treatment, both groups showed significant reductions in VAS scores compared to baseline. Furthermore, the combination group had significantly lower average scores than the monotherapy group (P<0.05) (**Table 2**; **Figure 1**).

*Comparison of tear film stability indicators*

No significant differences in BUT levels were observed between the groups before treatment (P>0.05). After treatment, BUT levels increased significantly in both groups compared to baseline (P<0.05), with the combination group demonstrating significantly higher levels than the monotherapy group (P<0.05) (**Figure 2**).

Pre-treatment SIt levels did not differ significantly between the groups (P>0.05). Post-treatment, both groups showed significant improvements in SIt levels (P<0.05). The combination group exhibited notably higher SIt levels compared to the monotherapy group after treatment (P<0.05) (**Table 3**; **Figure 3**).

*Comparison of inflammatory marker levels*

Before treatment, there was no statistically significant difference in serum TNF-α levels between the combination group (737.25 ± 84.40 ng/L) and the monotherapy group (771.10 ± 140.46 ng/L) (P> 0.05). After treatment, the TNF-α level in the combination group was significantly lower than that in the monotherapy group (188.43 ± 56.88 ng/L vs. 354.05 ± 85.16 ng/L; P<0.05) (**Figure 4**).

*Comparison of oxidative stress parameters*

No significant difference was observed in serum MMP-2 levels between the combination group (24.71 ± 3.84 ng/mL) and the monotherapy group (24.02 ± 4.26 ng/mL) before treatment (P>0.05). After treatment, the MMP-2 level in the combination group (11.27 ± 3.20 ng/mL) was significantly lower than that in the monotherapy group (16.25 ± 3.26 ng/mL; P<0.05) (**Figure 5**).

*Comparison of ocular surface indicators*

Before treatment, there were no significant differences in OSDI scores, conjunctival congestion grades, or TMH levels between the groups (all P>0.05). After treatment, all these indicators improved in both groups. The combination group demonstrated significantly lower OSDI scores and conjunctival congestion grades, and a higher TMH level compared to the monotherapy group (all P<0.05) (**Figure 6**).

*Comparison of NEI-VFQ-25 scale scores*

Before treatment, NEI-VFQ-25 scores did not differ significantly between the two groups (P>0.05). After treatment, patients in the combination group scored significantly higher in general health and vision, difficulty with activi-

**Table 3.** Comparison of tear film stability indicators between the two groups before and after treatment

| Group | Number | BUT (s) | | SIt (mm/5 min) | |
|---|---|---|---|---|---|
| | | Before treatment | After treatment | Before treatment | After treatment |
| Combination group | 40 | 5.45±1.08 | 12.05±2.74 | 5.23±1.10 | 10.68±2.41 |
| Monotherapy group | 40 | 5.68±1.16 | 9.18±1.93 | 5.75±1.30 | 7.33±1.67 |
| *t* | - | 0.918 | 5.416 | 1.931 | 7.226 |
| *P* | - | 0.362 | <0.001 | 0.057 | <0.001 |

BUT: break-up time; SIt: Schirmer I test.

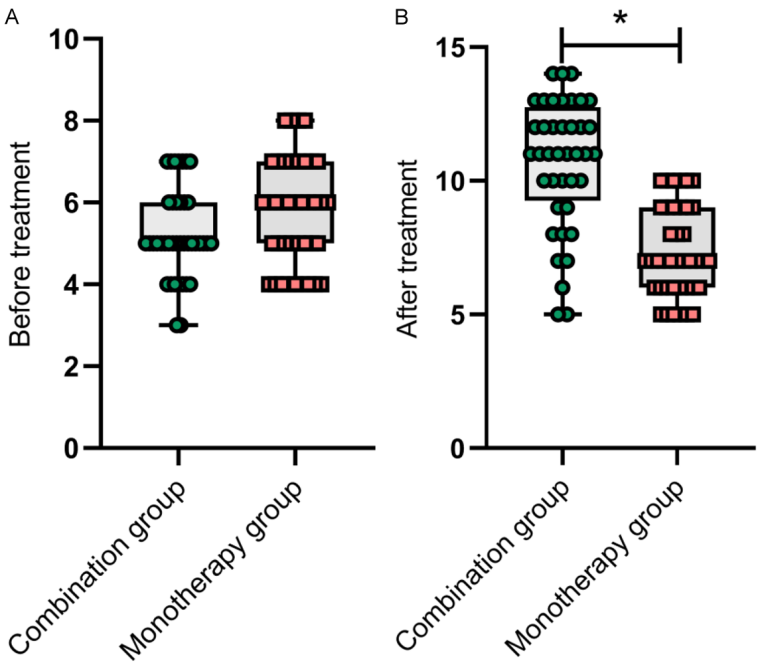


**Figure 3.** Comparison of SIt Levels between the two groups before and after treatment. There was no significant difference in pre-treatment SIt levels between the two groups (*P*>0.05). Post-treatment, however, SIt levels in the combination group were higher than those in the monotherapy group (*P*<0.05). An asterisk (*) signifies a statistically significant intergroup difference. SIt: Schirmer I test.

ties, responses to vision problems, and overall scores compared to the monotherapy group (P<0.05) (**Figure 7**).

*Comparison of incidence of adverse reactions*

During the 2-month follow-up, one case of ocular irritation occurred in the combination group, resulting in an adverse reaction incidence of 2.50% (1/40). In the monotherapy group, one case of ocular irritation, one case of elevated intraocular pressure, and one case of ocular infection were reported, with an overall incidence of 7.50% (3/40). The difference in adverse reaction rates between the two groups was not statistically significant (P>0.05) (**Figure 8**).

## Discussion

Dry eye disease is a prevalent condition characterized by ocular discomfort, visual fatigue, and impaired vision, significantly impacting patients' daily lives. Epidemiological studies report that its prevalence ranges from 7.8% to 34.0% globally and from 6.1% to 52.4% in China, with notable regional and ethnic variations [3, 15]. In recent years, lifestyle changes have contributed to an increasing incidence of dry eye disease among younger populations, highlighting the need for heightened clinical attention [16].

Early symptoms of dry eye disease are often mild and include dryness, photophobia, sensitivity to wind, tingling, and foreign body sensation. As the disease progresses, it can lead to a decline in visual quality, and in advanced stages, it may cause blepharospasm, irreversible damage to the cornea and conjunctiva, and, in severe cases, blindness. These outcomes have profound physical and psychological effects on patients, underscoring the importance of timely and effective interventions [17, 18].

Fluorometholone eye drops, a glucocorticoid, demonstrate potent anti-inflammatory, vasoconstrictive, and antipruritic effects, making them effective in managing ocular inflammation. They are widely used in treating conditions

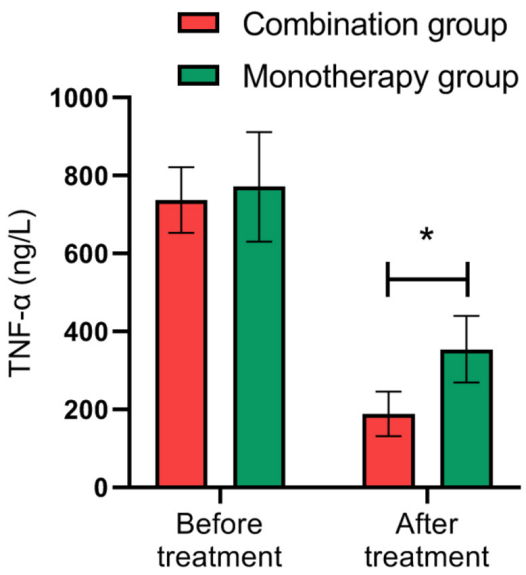


**Figure 4.** Comparison of serum TNF-α levels between the two groups before and after treatment. There was no statistically significant difference in serum TNF-α levels between the two groups of patients before treatment ($P$>0.05). After treatment, serum TNF-α levels in the combination group were significantly lower than those in the monotherapy group ($P$<0.05). * indicates a statistically significant difference between groups. TNF-α: tumor necrosis factor-α.

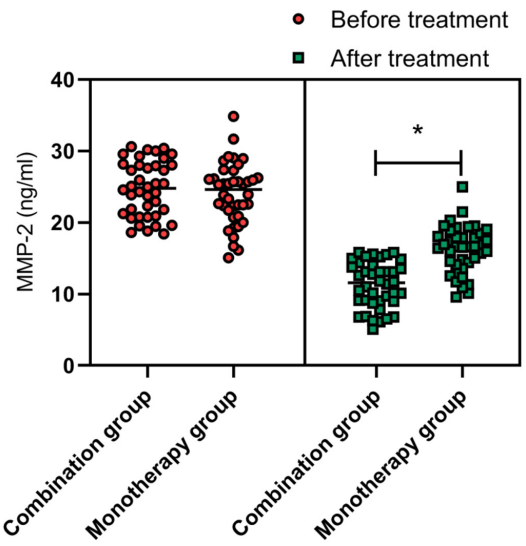


**Figure 5.** Comparison of MMP-2 levels between the two groups before and after treatment. Before treatment, there was no statistically significant difference in MMP-2 levels between the two groups of patients ($P$>0.05). After treatment, MMP-2 levels in the combination group were significantly lower than those in the monotherapy group ($P$<0.05). * indicates a statistically significant difference between groups. MMP-2: matrix metalloproteinase-2.

such as acute herpes simplex keratitis, fungal infections, and conjunctival inflammation [19]. Animal studies have shown that the pharmacological effects of Fluorometholone are comparable to those of dexamethasone, particularly in the treatment of uveitis. Clinically, Fluorometholone has proven effective in alleviating the symptoms of dry eye disease [20].

This study highlights the superior efficacy of combining Fluorometholone with Moisture Chamber Goggles compared to Fluorometholone monotherapy in treating dry eye disease. Previous research [21] suggests that corneal epithelial detachment in some patients triggers increased prostaglandin synthesis, leading to ocular inflammation, disruption of the blood-aqueous barrier, heightened pain receptor sensitivity, and a reduced itch threshold. These processes exacerbate the discomfort associated with dry eye disease.

While Fluorometholone mitigates inflammation by inhibiting the inflammatory response, the addition of Moisture Chamber Goggles enhances treatment by creating a humid ocular environment. The goggles form an enclosed space around the eye, reducing tear evaporation by limiting airflow over the ocular surface. This mechanism significantly improves subjective symptom scores (e.g., VAS) in patients with dry eye disease [22].

The findings of this study demonstrate that the combination of Moisture Chamber Goggles and Fluorometholone significantly enhances tear film stability in patients with dry eye disease. Tear film stability is a crucial parameter for assessing the clinical manifestations of dry eye, as its instability often results from excessive tear evaporation or mucin deficiency within the tear composition.

The efficacy of Fluorometholone, particularly in treating non-infectious inflammatory conditions, is attributed to its ability to inhibit the infiltration of inflammatory factors into normal tissue cells, reduce capillary permeability, and minimize vascular exudation. These effects stabilize cell membranes and suppress histamine synthesis by mast cells, thereby mitigating inflammation and promoting ocular health.

When combined with Moisture Chamber Goggles, the therapeutic effects of Fluorome-

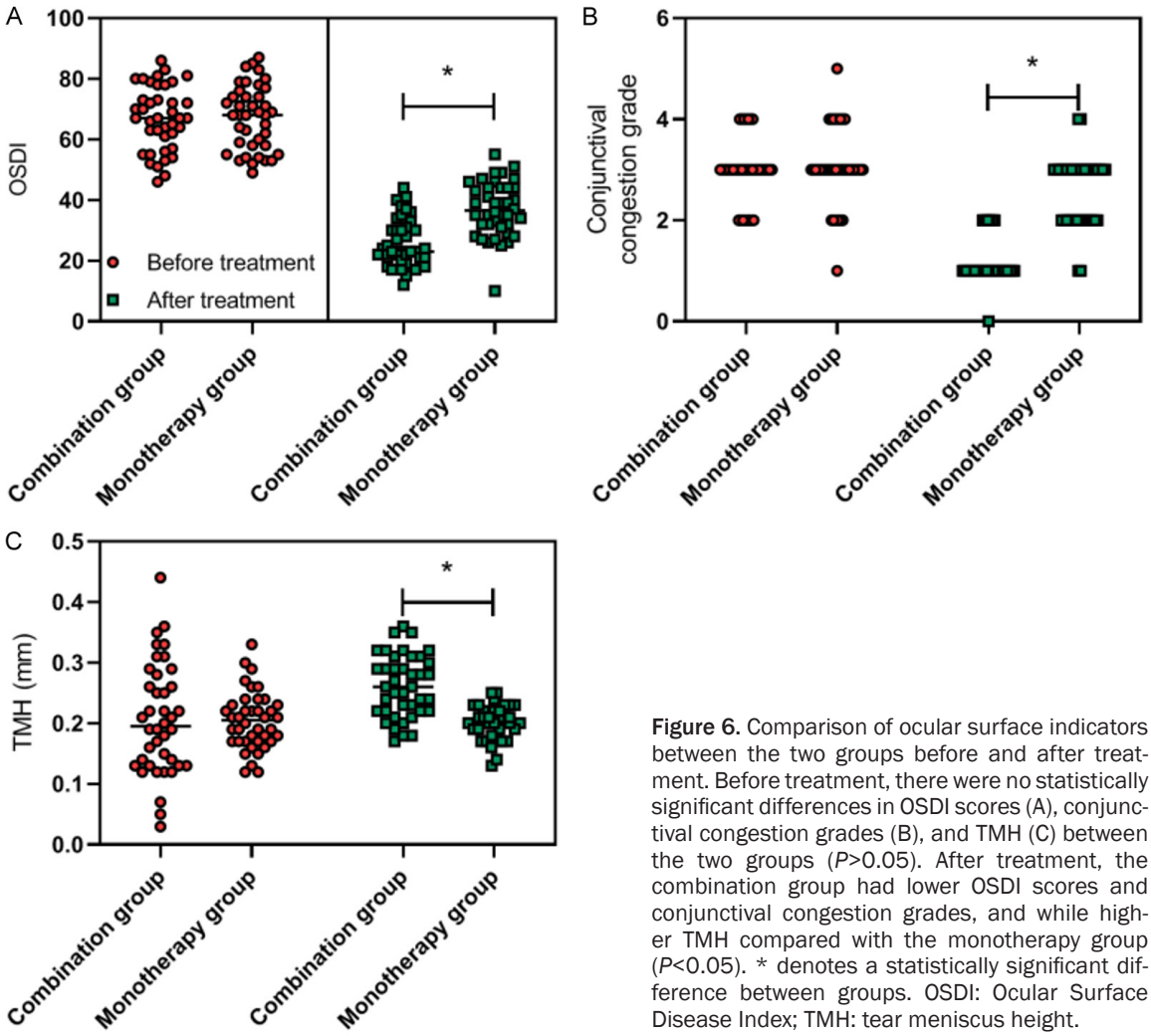


**Figure 6.** Comparison of ocular surface indicators between the two groups before and after treatment. Before treatment, there were no statistically significant differences in OSDI scores (A), conjunctival congestion grades (B), and TMH (C) between the two groups ($P>0.05$). After treatment, the combination group had lower OSDI scores and conjunctival congestion grades, and while higher TMH compared with the monotherapy group ($P<0.05$). * denotes a statistically significant difference between groups. OSDI: Ocular Surface Disease Index; TMH: tear meniscus height.

tholone are further enhanced. The goggles create a relatively isolated environment around the eyes, reducing tear evaporation, increasing ocular surface humidity, and elevating periocular temperature. Additionally, the goggles help trap evaporated moisture, effectively serving as a protective barrier for tear retention [23]. A stable and sufficient tear film is essential for maintaining ocular surface homeostasis, as it supports epithelial cell proliferation, alleviates ocular discomfort, and improves tear film stability. This combined therapy not only addresses the inflammatory processes underlying dry eye disease but also preserves the integrity of the tear film, providing a comprehensive approach to managing dry eye symptoms.

This study also compared inflammatory and oxidative stress markers between the combination and monotherapy groups before and after treatment. Results showed that the combination group had significantly lower post-treatment MMP-2 levels. MMP-2, a matrix metalloproteinase, is primarily involved in degrading components of the extracellular matrix. Its role is closely tied to oxidative stress, a condition characterized by cellular damage due to excessive production of reactive oxygen species (ROS) or reactive nitrogen species (RNS) or an impaired antioxidant system.

The relationship between MMP-2 and oxidative stress is multifaceted: Oxidative stress leads to the excessive accumulation of intracellular ROS, such as superoxide and hydrogen peroxide, which can activate MMP-2 directly or indirectly through various signaling pathways. Oxidative stress results in tissue damage, while

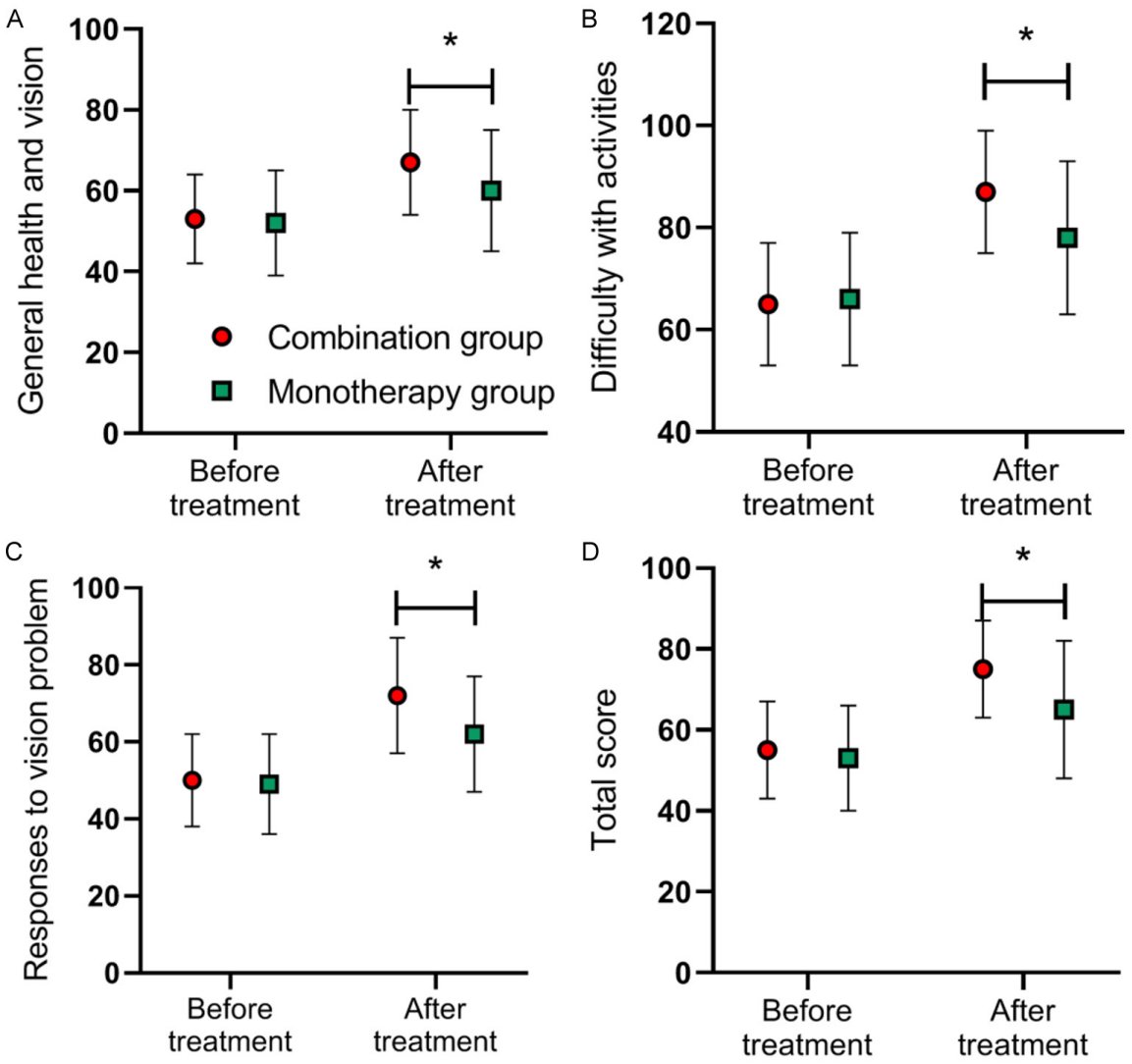


**Figure 7.** Comparison of NEI-VFQ-25 scale scores between the two groups before and after treatment. Before treatment, there were no statistically significant differences in NEI-VFQ-25 scale scores between the two groups ($P>0.05$). After treatment, the combination group had significantly higher scores in general health and vision (A), difficulty with activities (B), responses to vision problems (C), and overall scores (D) compared to the monotherapy group ($P<0.05$). * denotes a statistically significant difference between groups. NEI-VFQ-25: The National Eye Institute Visual Function Questionnaire-25.

the overexpression of MMP-2 exacerbates extracellular matrix degradation, accelerating tissue injury and fibrosis.

This creates a vicious cycle, wherein elevated MMP-2 levels further enhance oxidative stress, which in turn activates MMP-2 activity [24]. By significantly reducing MMP-2 levels, the combination therapy disrupts this cycle, mitigating oxidative stress and its associated tissue damage.

This study also evaluated the safety profile of the treatments. The findings indicate that the use of Moisture Chamber Goggles did not increase the incidence of adverse reactions. In contrast, a higher rate of adverse reactions was observed in the monotherapy group. The potential reasons for this difference are as follows: (1) Moisture Chamber Goggles act as a physical barrier, effectively preventing dust, chemicals, and other irritants from entering the eyes. This barrier reduces the risk of eye infections, particularly in humid or chemically contaminated environments. Additionally, the goggles maintain ocular surface hydration, alleviating dryness-induced discomfort. This protective

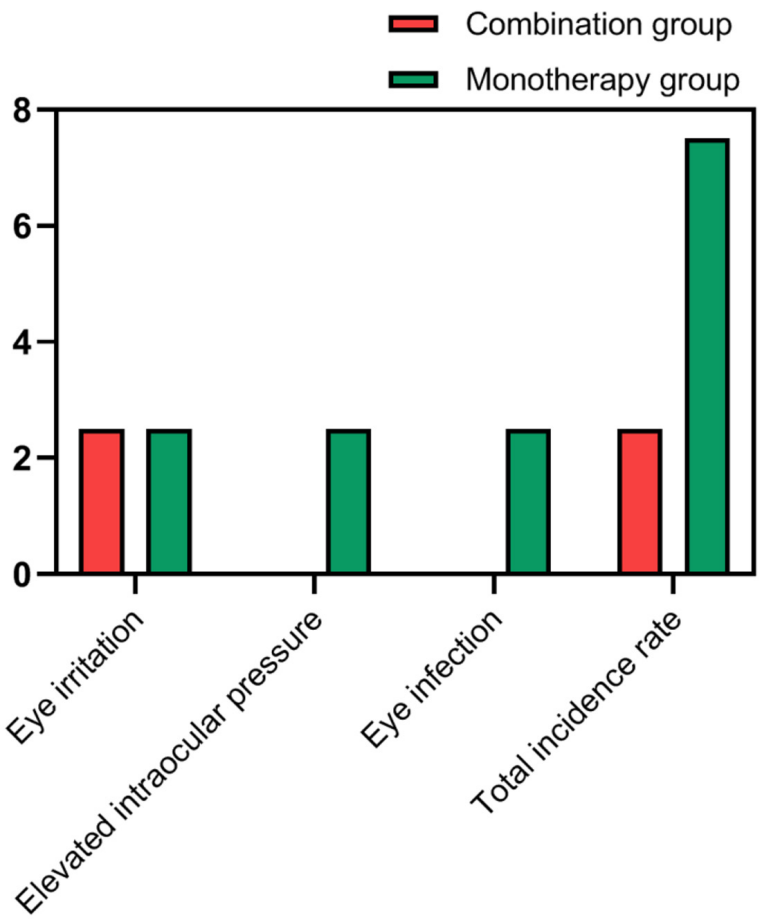


**Figure 8.** Comparison of adverse reaction incidence between the two groups. The incidence of adverse reactions in the combination group was 2.50%, which was not significantly different from the 7.50% incidence observed in the monotherapy group ($P$>0.05).

function is especially beneficial for vulnerable populations, such as individuals with dry eye syndrome. (2) Fluorometholone, a steroid medication, reduces ocular inflammation by inhibiting the release of inflammatory mediators. This action alleviates symptoms such as redness, pain, and discomfort, thereby promoting overall eye health. In some cases, Fluorometholone may also facilitate the healing of ocular tissues, indirectly reducing the risk of infection associated with eye injuries. Although steroids lack direct antibacterial properties, effective inflammation control can lower infection susceptibility. These mechanisms contribute to the superior safety profile of the combined intervention compared to monotherapy.

This study validated the clinical value of the combined utilization of Moisture Chamber Goggles and Fluorometholone eye drops in patients with dry eye disease through a comparative analysis. Although the data obtained are instructive, the study is not devoid of limitations. Specifically, the sample size was relatively small, the follow-up period was brief, and it was a single-center study. Owing to the characteristics of the study, the selection of observational indicators was also rather restricted. In the future, a large-scale, multicenter study with long-term follow-up will be carried out to further explore the effective mechanisms of this combined treatment from a molecular perspective.

In conclusion, the combined use of Moisture Chamber Goggles and Fluorometholone eye drops in patients with dry eye disease significantly improves subjective visual quality, promotes tear secretion, enhances tear film stability, and reduces serum levels of inflammatory markers and oxidative stress indicators. Moreover, the treatment is associated with a favorable safety profile, highlighting its considerable clinical value in managing dry eye disease.

## Disclosure of conflict of interest

None.

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