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Efficacy and Safety of Intense Pulsed Light Combined with Conventional Therapy for Moderate-to-Severe Video Display Terminal-Associated Dry Eye: A Retrospective Controlled Study

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Abstract

Objective

To evaluate the clinical efficacy, onset characteristics, and safety of intense pulsed light (IPL) combined with conventional therapy for the treatment of moderate-to-severe video display terminal (VDT)-associated dry eye.

Methods

A retrospective controlled study was conducted on 100 patients (200 eyes) diagnosed with moderate-to-severe VDT-associated dry eye from June 2022 to September 2026. All enrolled patients were divided into two groups: Group A (50 patients, 100 eyes) received combined treatment with meibomian gland expression and topical medications, while Group B (50 patients, 100 eyes) received additional IPL therapy on the basis of the conventional regimen. Outcome measures including the ocular surface disease index (OSDI), non-invasive tear meniscus height (NITMH), non-invasive break up time (NIBUT), schirmer I test (SIT), eyelid margin score (EMS), meibomian gland yielding secretion score (MGYSS), corneal fluorescein staining score (CFSS), and meibomian gland loss score (MGLS) were assessed at baseline, 1 week, 4 weeks, 7 weeks, and 10 weeks after treatment. Generalized estimating equations were applied to address the correlation of binocular data, and repeated-measures analysis of variance and non-parametric tests were used for statistical analysis.

Results

At 10 weeks post-treatment, all dry eye-related indicators were significantly improved in Group A except for MGLS, whereas all indicators were remarkably ameliorated in Group B. Group B exhibited significantly superior improvements in OSDI, NITMH, NIBUT, SIT, EMS, MGYSS, and CFSS compared with Group A, with no significant between-group difference observed in MGLS. Moreover, Group B achieved obvious therapeutic effects as early as 1 week after treatment, while stable clinical improvements were only observed at 4 weeks in Group A. No severe adverse events occurred in either group throughout the follow-up period.

Conclusion

IPL combined with conventional therapy provides faster and more robust therapeutic efficacy with favorable safety for moderate-to-severe VDT-associated dry eye. This combined regimen can be recommended as a first-line adjuvant therapeutic strategy for such patients.

Introduction

Dry eye disease (DED) is a multifactorial symptomatic disorder characterized by dysregulation of tear film and/or ocular surface homeostasis, among which the digital environment is one of the major lifestyle factors affecting ocular surface health[1]. With the popularization of information-based lifestyles, video display terminal (VDT) such as mobile phones and computers have become the primary carriers for daily work and entertainment. As the daily screen time of the general population continues to increase, the prevalence of VDT-associated dry eye has risen significantly[2–5]. VDT can induce dry eye through multiple direct and indirect pathways. Reduced blink rate and increased incomplete blinks enlarge the evaporative area of the tear film on the ocular surface and impede the normal distribution of meibomian gland lipids. In addition, alterations in parasympathetic nerve signaling may impair lacrimal gland and goblet cell function, exacerbating tear film instability[6]. Furthermore, prolonged VDT exposure affects the structure and function of meibomian glands, and meibomian gland dysfunction (MGD) is associated with the severity of dry eye in VDT workers[7]. VDT-associated dry eye not only impairs patients' quality of life but also negatively impacts their work productivity, and has become a major public health concern[8].

Conventional treatments, including topical pharmacotherapies such as artificial tears and anti-inflammatory agents, as well as meibomian gland expression (MGE), can alleviate symptoms to a certain extent, but they have limitations such as short duration of therapeutic effect and poor patient compliance[9,10]. The intense pulsed light (IPL) system is a high-intensity light source that emits polychromatic incoherent light with wavelengths ranging from 515 to 1200 nanometers, including visible and infrared light[11]. Previous studies have found a significant association between dry eye and inflammatory skin disorders occurring near the eyelids, such as facial rosacea. Patients receiving IPL treatment for facial rosacea have shown significant improvement in their dry eye symptoms simultaneously[12]. In recent years, IPL therapy, as an emerging physical therapy modality, has demonstrated promising potential in the treatment of dry eye disease[13]. The underlying mechanisms of IPL for dry eye include softening meibum via thermal effect to promote meibomian gland secretion, coagulating abnormally dilated capillaries to reduce pro-inflammatory markers, and inhibiting the proliferation of bacteria and microorganisms on the eyelid margin[12,14].

IPL therapy is clinically effective in relieving the signs and symptoms of severe evaporative dry eye disease[15]. A multicenter study showed that IPL combined with MGE improved symptoms, meibomian gland secretion, and tear film parameters in patients with refractory MGD-associated dry eye[16]. Preoperative IPL combined with MGE intervention for MGD-associated dry eye in patients undergoing cataract surgery can enhance tear film stability, improve ocular surface status and postoperative visual outcomes, help optimize postoperative visual quality, and increase patient satisfaction[17]. In individuals using topical anti-glaucoma medications, untreated ocular surface disease may deteriorate, while IPL treatment can significantly improve the signs and symptoms of dry eye in these patients[18]. Dry eye is common in patients undergoing laser-assisted in situ keratomileusis, and IPL has a positive impact on both subjective and objective outcomes of dry eye[19]. In addition, IPL therapy can safely alleviate contact

lens-related dry eye, reduce symptom severity, improve overall tear film stability, and decrease the frequency of artificial tear use[20]. IPL combined with MGE or 0.05% cyclosporine A can significantly improve the subjective symptoms and objective parameters of Sjögren's syndrome-associated dry eye, representing a promising therapeutic strategy[21,22]. However, for the specific population with moderate-to-severe VDT-associated dry eye, controlled studies on the temporal onset pattern of efficacy, multidimensional quantitative efficacy, and safety of IPL combined with conventional treatment are still relatively scarce, and unified clinical evidence-based guidelines are lacking.

This study adopted a retrospective controlled design and enrolled patients with moderate-to-severe VDT-associated dry eye. Two treatment regimens were compared: the group A (MGE + pharmacotherapy) and the group B (IPL + MGE + pharmacotherapy). Multi-time point follow-up assessments were performed to evaluate indicators including subjective symptom scores, tear secretion, tear film function, eyelid margin and meibomian gland function, and corneal epithelial damage. The aim of this study was to clarify the onset characteristics, clinical efficacy, and safety of IPL in the treatment of moderate-to-severe VDT-associated dry eye, and to provide evidence-based support for the clinical optimization of individualized comprehensive treatment strategies.

Subjects and Methods

This study is a retrospective study, including moderate to severe VDT related dry eye patients who were treated in the Second Affiliated Hospital of Nanchang University from June 2022 to September 2026. Inclusion criteria: aged 20–60 years; VDT workers; Daily use time of VDT ≥ 4 hours; Meet the diagnostic criteria of dry eye. Exclusion criteria: Corneal contact lens wearing history; Local eye lesions such as blepharitis, keratitis, eyelid defects, incomplete eyelid closure, etc; Have immune related diseases or other serious systemic diseases; Recently used drugs that may affect ocular surface status. A total of 103 patients were initially enrolled. Of these, 3 were lost to follow-up, and the remaining 100 were included in the final analysis. All patients signed informed consent, and the study followed the principles of the declaration of Helsinki. This study was approved by the Ethical Review Committee of the Second Affiliated Hospital of Nanchang University [approval number: O-Medical Research Ethics Review [2026]No. (280)].

Grouping and Treatment

Group A (MGE + pharmacotherapy): Patients were placed in the supine position. After topical anesthesia with proparacaine hydrochloride eye drops (Alcaine), meibomian gland expression was performed using a rounded-tip glass rod. The rod was gently applied from the conjunctival fornix outward along the anatomical course of the meibomian glands, sequentially expressing the lower eyelid followed by the upper eyelid to evacuate obstructed meibomian secretions. Following expression, patients were prescribed pranoprofen eye drops (Pranopulin) and 0.1% sodium hyaluronate eye drops (Hyalud), both administered as 1 drop four times daily. MGE was treated every 3 weeks for a total of 4 times.

Group B (IPL + MGE + pharmacotherapy): IPL treatment was performed using the EYESIS IPL dry eye therapeutic device. Patients kept their eyes closed and wore protective ceramic goggles. Ultrasound conductive gel was applied to the facial skin. Treatment energy was set at 10–15 J/cm². Four consecutive pulses were delivered from the nasal to temporal side, followed by one horizontal pulse along the lower edge of the goggles. Both eyes were treated sequentially. Immediately after IPL treatment, identical meibomian gland expression and pharmacotherapy as described for Group A were administered. All treatments were performed by a single trained operator to minimize inter-operator variability. IPL and MGE were treated every 3 weeks for a total of 4 times.

Observation Indicators

All assessments were performed by the same trained ophthalmologist before treatment and at 1, 4, 7, and 10 weeks after treatment.

Ocular Surface Disease Index (OSDI)

The OSDI score was used to evaluate dry eye-related subjective symptoms.

Non-invasive Tear Meniscus Height (NITMH)

Measured using the K5M ocular surface analyzer. The height of the tear meniscus was marked at the junction of the light strip on the corneal-conjunctival surface and the light strip on the lower eyelid margin.

Non-invasive Tear Film Break-up Time (NIBUT)

Measured using the K5M ocular surface analyzer. Patients blinked twice and then opened their eyes naturally, keeping them open for as long as possible. NIBUT was measured once every 5 minutes, and the average of 3 measurements was taken.

Schirmer I Test (SIT)

Without topical anesthesia, a standard filter paper strip was placed for 5 minutes, and the wet length (mm) was measured.

Eyelid Margin Score (EMS): Eyelid margin morphology was observed under slit-lamp microscopy. Evaluation criteria: 0 = no eyelid margin congestion; 1 = mild eyelid margin congestion with capillary dilation around gland orifices; 2 = moderate eyelid margin congestion; 3 = rounding, thickening, neovascularization of the posterior eyelid margin, or eczema and irregular eyelid margin. Total score: 0–3.

Meibomian Gland Secretion Score (MGYSS): The properties of meibum expressed from gland orifices were scored under slit-lamp microscopy. Evaluation criteria: 0 = clear and transparent; 1 = turbid, lipid

liquid; 2 = turbid with debris or granules; 3 = thick, toothpaste-like. Total score: 0–3.

Corneal Fluorescein Staining Score (CFSS): 2% sodium fluorescein was instilled into the conjunctival sac, and corneal staining was observed under cobalt blue light. Evaluation criteria: 0 = no staining; 1 = 1–30 punctate staining spots; 2 = more than 30 punctate staining spots without fusion; 3 = fused punctate staining, filaments, or ulcers on the cornea. The cornea was divided into 4 quadrants, with a total score of 0–12.

Meibomian Gland Loss Score (MGLS): After infrared photography of the eyelids, analysis was performed using ImageJ software. The area of meibomian gland loss was graded as follows: 0 = normal meibomian glands; 1 = loss < 1/3; 2 = loss 1/3 − 2/3; 3 = loss > 2/3. Total score for upper and lower eyelids of a single eye: 0–6.

Statistical Analysis

All statistical data were expressed as mean ± standard deviation, and statistical analysis was performed using SPSS 26.0 software. Age, VDT time, and sex distribution should be compared using independent-sample t-test (or Mann-Whitney U test) and chi-square test, respectively. Generalized estimating equation was used to compare differences in dry eye indicators between the two groups. For differences in dry eye indicators before and after treatment, data that met the normal distribution were analyzed using repeated measures analysis of variance (ANOVA), and data that did not meet the normal distribution were analyzed using non-parametric tests. A P-value < 0.05 was considered statistically significant.

Results

Comparison of Baseline Characteristics Between the Two Groups

A total of 100 patients with VDT-related dry eye were enrolled in this study, including 50 patients (100 eyes) in group A and 50 patients (100 eyes) in group B. No statistically significant differences were observed between the two groups in terms of gender, age, average daily video time, or baseline dry eye parameters including OSDI, NITMH, NIBUT, SIT, EMS, MGYSS, CFSS, and MGLS (Table 1).

Table 1
Baseline Characteristics of Patients

Gender (M/F)	**Group A (n = 100 eyes)**	**Group B (n = 100 eyes)**	***P***
	24/26	**22/28**	**0.777**
Age (years)	39.08 ± 7.13	40.72 ± 9.30	0.325
VDT time(h)	7.52 ± 1.69	7.68 ± 1.89	0.657
OSDI (score)	58.66 ± 11.72	59.16 ± 16.24	0.860
NITMH (mm)	0.16 ± 0.02	0.15 ± 0.03	0.212
NIBUT (s)	4.63 ± 1.61	4.39 ± 1.08	0.373
SIT (mm/5min)	4.82 ± 1.33	4.66 ± 1.05	0.506
EMS (score)	2.04 ± 0.67	2.02 ± 0.74	0.898
MGYSS (score)	2.02 ± 0.69	2.06 ± 0.74	0.767
CFSS (score)	1.86 ± 1.11	1.92 ± 1.12	0.755
MGLS (score)	2.06 ± 1.06	2.02 ± 1.19	0.853
Notes (M: Male; F: Female)			

Comparison of Changes in Dry Eye Parameters Between the Two Groups After Treatment

OSDI

Within-group comparisons demonstrated statistically significant improvements in OSDI scores from baseline to 1, 4, 7, and 10 weeks post-treatment in both group A and group B (all $P < 0.05$). Between-group comparisons showed no statistically significant difference in OSDI scores at baseline ($P = 0.860$) or 1 week post-treatment ($P = 0.692$). However, statistically significant differences between the two groups emerged at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 2).

Table 2
Comparison of OSDI, NITMH, NIBUT and SIT

		Group A (n = 100 eyes)	Group B (n = 100 eyes)	*P* (A vs B)
OSDI (score)	0 W	58.66 ± 11.72	59.16 ± 16.24	0.860
	1 W	53.02 ± 15.76	51.78 ± 15.49	0.692
	P (1 W vs 0 W)	< 0.001	< 0.001	/
	4 W	45.80 ± 14.09	39.96 ± 12.80	0.032
	P (4 W vs 0 W)	< 0.001	< 0.001	/
	7 W	36.74 ± 10.24	32.48 ± 8.80	0.028
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	33.20 ± 10.40	28.10 ± 8.28	0.008
	P (10 W vs 0 W)	< 0.001	< 0.001	/
NITMH (mm)	0 W	0.16 ± 0.03	0.15 ± 0.03	0.212
	1 W	0.16 ± 0.03	0.17 ± 0.03	0.202
	P (1 W vs 0 W)	0.889	< 0.001	/
	4 W	0.17 ± 0.03	0.19 ± 0.03	0.041
	P (4 W vs 0 W)	0.005	< 0.001	/
	7 W	0.18 ± 0.02	0.20 ± 0.03	0.001
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	0.19 ± 0.02	0.21 ± 0.03	< 0.001
	P (10 W vs 0 W)	< 0.001	< 0.001	/
NIBUT (s)	0 W	4.63 ± 1.61	4.39 ± 1.08	0.373
	1 W	5.08 ± 1.72	5.31 ± 1.77	0.515
	P (1 W vs 0 W)	0.403	0.001	/
	4 W	5.54 ± 1.59	6.17 ± 1.56	0.047
	P (4 W vs 0 W)	< 0.001	< 0.001	/
	7 W	6.77 ± 1.37	7.72 ± 1.52	0.001
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	7.37 ± 1.61	8.82 ± 1.64	< 0.001
	P (10 W vs 0 W)	< 0.001	< 0.001	/

SIT (mm/5min)	0 W	4.82 ± 1.33	4.66 ± 1.05	0.506
	1 W	5.22 ± 1.44	5.62 ± 1.41	0.163
	P (1 W vs 0 W)	0.198	< 0.001	/
	4 W	5.89 ± 1.42	6.51 ± 1.32	0.026
	P (4 W vs 0 W)	< 0.001	< 0.001	/
	7 W	7.14 ± 1.74	8.20 ± 1.53	0.002
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	8.35 ± 1.74	9.65 ± 2.16	0.001
	P (10 W vs 0 W)	< 0.001	< 0.001	/

NITMH

In group A, no statistically significant change in NITMH was observed between baseline and 1 week post-treatment ($P = 0.889$), but significant improvements were detected from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, NITMH values improved significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$).Between-group comparisons revealed no statistically significant difference in NITMH at baseline ($P = 0.212$) or 1 week post-treatment ($P = 0.202$). Statistically significant differences between the two groups were present at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 2).

NIBUT

In group A, there was no statistically significant difference in NIBUT between baseline and 1 week post-treatment ($P = 0.403$), while significant prolongations were observed from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, NIBUT values improved significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$). Between-group comparisons showed no statistically significant difference in NIBUT at baseline ($P = 0.373$) or 1 week post-treatment ($P = 0.515$). However, statistically significant differences between the two groups were noted at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 2).

SIT

In group A, no statistically significant change in SIT values was found between baseline and 1 week post-treatment ($P = 0.198$), but significant increases were detected from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, SIT values improved significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$). Between-group comparisons revealed no statistically significant difference in SIT values at baseline ($P = 0.506$) or 1 week post-treatment ($P = 0.163$).

Statistically significant differences between the two groups were observed at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 2).

EMS

Within-group comparisons showed no statistically significant reduction in EMS scores between baseline and 1 week post-treatment in group A ($P = 0.083$), but significant improvements were observed from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, EMS scores decreased significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$).Between-group comparisons revealed no statistically significant difference in EMS scores at baseline ($P = 0.898$) or 1 week post-treatment ($P = 0.135$). However, statistically significant differences between the two groups emerged at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 3).

Table 3
Comparison of EMS, MGYSS, CFSS and MGLS

		Group A (n = 100 eyes)	Group B (n = 100 eyes)	*P* (A vs B)
EMS (score)	0 W	2.04 ± 0.67	2.02 ± 0.74	0.898
	1 W	1.98 ± 0.80	1.78 ± 0.82	0.135
	P (1 W vs 0 W)	0.083	0.001	/
	4 W	1.70 ± 0.54	1.46 ± 0.61	0.028
	P (4 W vs 0 W)	0.001	< 0.001	
	7 W	1.22 ± 0.55	0.88 ± 0.39	0.001
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	0.88 ± 0.39	0.58 ± 0.54	0.002
	P (10 W vs 0 W)	< 0.001	< 0.001	/
MGYSS (score)	0 W	2.02 ± 0.69	2.06 ± 0.74	0.767
	1 W	1.96 ± 0.81	1.84 ± 0.68	0.286
	P (1 W vs 0 W)	0.083	0.016	/
	4 W	1.66 ± 0.59	1.38 ± 0.70	0.041
	P (4 W vs 0 W)	0.001	< 0.001	/
	7 W	1.16 ± 0.51	0.82 ± 0.39	< 0.001
	P (7 W vs 0 W)	< 0.001	< 0.001	/
	10 W	0.82 ± 0.39	0.36 ± 0.49	< 0.001
	P (10 W vs 0 W)	< 0.001	< 0.001	/
CFSS (score)	0 W	1.86 ± 1.11	1.92 ± 1.12	0.755
	1 W	1.82 ± 1.16	1.74 ± 1.32	0.883
	P (1 W vs 0 W)	0.157	0.003	/
	4 W	1.74 ± 1.19	1.26 ± 1.03	0.046
	P (4 W vs 0 W)	0.014	< 0.001	/
	7 W	1.66 ± 1.17	1.02 ± 1.12	0.004
	P (7 W vs 0 W)	0.004	< 0.001	/
	10 W	1.36 ± 1.32	0.60 ± 1.05	0.002
	P (10 W vs 0 W)	< 0.001	< 0.001	/

MGLS (score)	0 W	2.06 ± 1.06	2.02 ± 1.19	0.853
	1 W	2.06 ± 1.06	2.00 ± 1.21	0.814
	P (1 W vs 0 W)	1.000	0.317	/
	4 W	2.04 ± 1.09	2.00 ± 1.21	0.858
	P (4 W vs 0 W)	0.317	0.317	/
	7 W	2.02 ± 1.12	1.98 ± 1.12	0.911
	P (7 W vs 0 W)	0.157	0.083	/
	10 W	1.98 ± 1.12	1.88 ± 1.21	0.603
	P (10 W vs 0 W)	0.083	0.008	/

MGYSS

In group A, no statistically significant change in MGYSS scores was detected between baseline and 1 week post-treatment ($P = 0.083$), while significant reductions were noted from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, MGYSS scores improved significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$).Between-group comparisons showed no statistically significant difference in MGYSS scores at baseline ($P = 0.546$) or 1 week post-treatment ($P = 0.286$). Statistically significant differences between the two groups were present at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 3).

CFSS

Within-group comparisons demonstrated no statistically significant reduction in CFSS scores between baseline and 1 week post-treatment in group A ($P = 0.157$), but significant improvements were observed from baseline to 4, 7, and 10 weeks post-treatment (all $P < 0.05$). In group B, CFSS scores decreased significantly from baseline to all post-treatment time points (1, 4, 7, and 10 weeks; all $P < 0.05$).Between-group comparisons revealed no statistically significant difference in CFSS scores at baseline ($P = 0.552$) or 1 week post-treatment $P = 0.883$). However, statistically significant differences between the two groups were noted at 4, 7, and 10 weeks post-treatment (all $P < 0.05$) (Table 3).

MGLS

In group A, no statistically significant changes in MGLS scores were observed at any post-treatment time point compared with baseline (1 week: no change; 4 weeks: $P = 0.317$; 7 weeks: $P = 0.157$; 10 weeks: $P = 0.083$). In group B, no statistically significant differences in MGLS scores were found between baseline and 1 week ($P = 0.317$), 4 weeks ($P = 0.317$), or 7 weeks ($P = 0.083$) post-treatment, while a significant reduction was detected only at 10 weeks post-treatment ($P < 0.05$).Between-group comparisons showed no statistically significant difference in MGLS scores at any time point (baseline: $P = 0.704$; 1 week: $P = 0.814$; 4 weeks: $P = 0.858$; 7 weeks: $P = 0.911$; 10 weeks: $P = 0.603$) (Table 3).

As shown in Fig. 1, Group B demonstrated earlier, faster, and greater improvements in OSDI, NITMH, NIBUT, SIT, EMS, MGYSS, and CFSS starting from week 1. In contrast, Group A exhibited delayed improvements that became evident only after week 4, with a smoother but slower upward trend. The MGLS curves in both groups remained almost overlapping throughout the entire follow-up, with only a mild decrease in Group B at the final visit, suggesting that structural atrophy of the meibomian glands is difficult to reverse in the short term (Fig. 1).

Safety

Regarding safety, no significant changes were observed in visual acuity, intraocular pressure (IOP), periorbital skin, eyelashes, cornea, conjunctiva, iris, or lens in the IPL treatment group compared with baseline.

Representative Cases

As shown in Fig. 2, Compared with before treatment, NIBUT (Fig. 2A) and NITMH (Fig. 2B) were increased, while CFSS (Fig. 2C) was decreased. Before treatment, the eyelid margin showed hyperemia and hypertrophy, and the meibomian gland orifices exhibited granular turbid secretions; the meibomian glands were tortuous with partial loss. At 10 weeks after treatment, eyelid margin hyperemia and hypertrophy were markedly alleviated, meibomian gland secretions became clear and transparent (Fig. 2D), some glandular ducts became more regular in shape, and the area of gland loss was reduced (Fig. 2E).

Discussion

With the widespread use of video display terminals such as smartphones and computers, prolonged VDT exposure has become a major risk factor for ocular health in modern humans, severely impairing visual health and quality of life, and has emerged as a global public health concern of widespread attention. Long-term VDT exposure affects the structure and function of the meibomian glands. Meibomian gland dysfunction, as the core pathological link of VDT-associated dry eye, is not only an important cause of deficiency of the tear film lipid layer but also a key target for clinical intervention[7].

In this study, we compared the therapeutic efficacy between the group A (MGE + pharmacotherapy) and the group B (IPL + MGE + pharmacotherapy) in patients with moderate-to-severe VDT-associated dry eye, and systematically evaluated the dynamic changes at multiple time points. The results showed that after 10 weeks of standardized intervention, all dry eye indicators except MGLS were significantly improved in the conventional group, confirming that meibomian gland expression, artificial tears, and topical anti-inflammatory drugs have definite clinical efficacy for moderate-to-severe VDT-associated dry eye, which is consistent with the results of previous literature[23, 24]. Between-group comparisons revealed that the IPL combination group had significantly superior improvements in subjective symptoms, tear film stability, tear secretion, eyelid margin inflammation, and repair of corneal epithelial damage compared with the control group, while there was no significant difference in MGLS between the two groups. The

underlying reason is that meibomian gland atrophy and area loss are structural pathological changes. Short-term interventions with drugs, massage, and IPL can only unblock obstructed glandular ducts, improve lipid secretion and inflammatory status, and are difficult to completely reverse the established moderate-to-severe glandular tissue defects, although they may have a certain ameliorative effect on mild glandular morphological changes. This result is consistent with the conclusions of previous meibomian gland morphological studie[25, 26].

A significant temporal difference in treatment onset was observed in this study: the conventional group required 4 weeks of treatment to achieve sustained therapeutic effect, while the IPL combination group showed significant improvements in both symptoms and signs as early as 1 week after treatment, reflecting the clinical advantage of rapid onset of IPL combination therapy[13, 27]. The possible mechanisms by which IPL improves dry eye include: First, IPL is specifically absorbed by hemoglobin and lipid tissues around the meibomian glands through the selective photothermal effect, restoring normal meibum secretion, reducing tear evaporation rate, and reconstructing the integrity of the tear film lipid layer[12, 28]. Second, IPL can inhibit the release of inflammatory factors, downregulate the excessive activation of local immune cells, block the inflammatory cascade, and delay the progression of ocular surface damage[12, 29, 30]. Third, IPL can significantly improve the microstructural parameters of the meibomian glands, including the maximum diameter of meibomian gland acini, the unit density of meibomian glands, and periglandular inflammatory cells[31].

This study has several limitations. First, the sample size was relatively small, which may lead to selection bias. Second, the follow-up duration was short, with only 10 weeks of follow-up in this study. Thus, future studies with larger sample sizes and longer follow-up periods are needed to further investigate the long-term efficacy and durability of IPL in the treatment of moderate-to-severe VDT-associated dry eye. Third, this was a single-center retrospective study, and large-scale, multicenter, prospective randomized controlled trials are needed to further validate the findings of this study.

In conclusion, the addition of IPL to conventional meibomian gland expression combined with pharmacotherapy for moderate-to-severe VDT-associated dry eye results in faster onset of action, more significant improvements in both subjective symptoms and objective signs, and reliable safety. IPL can serve as a safe and effective first-line adjuvant treatment option for moderate-to-severe VDT-associated dry eye, with high clinical application and promotion value.

Conclusion

IPL combined with conventional therapy provides faster and more robust therapeutic efficacy with favorable safety for moderate-to-severe VDT-associated dry eye. This combined regimen can be recommended as a first-line adjuvant therapeutic strategy for such patients.

Declarations

Consent for publication:

Not Applicable. No identifiable individual patient images, personal clinical identifiers or sensitive private information are presented in this manuscript. All slit-lamp photographs, meibography infrared images and ocular surface analyzer output figures only display objective ocular surface and meibomian gland morphological parameters without any markers that could trace back to specific patients.

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Author Contribution

The authors report there are no competing interests to declare. C.L., H.H. and Q.J. were responsible for the data collection, data analysis, and manuscript writing. L.W. and Y.H. helped in data collection, and data analysis. Z.P.was helpful in data analysis and manuscript writing.Y.H.and Q.J. were responsible for conception and design, revision of the manuscript,and final manuscript approval.All authors contributed to the article and approved the submitted version.

Data Availability

Clinical data of patients with moderate-to-severe VDT-associated dry eye were retrospectively collected and statistically analyzed in this study.

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Figures

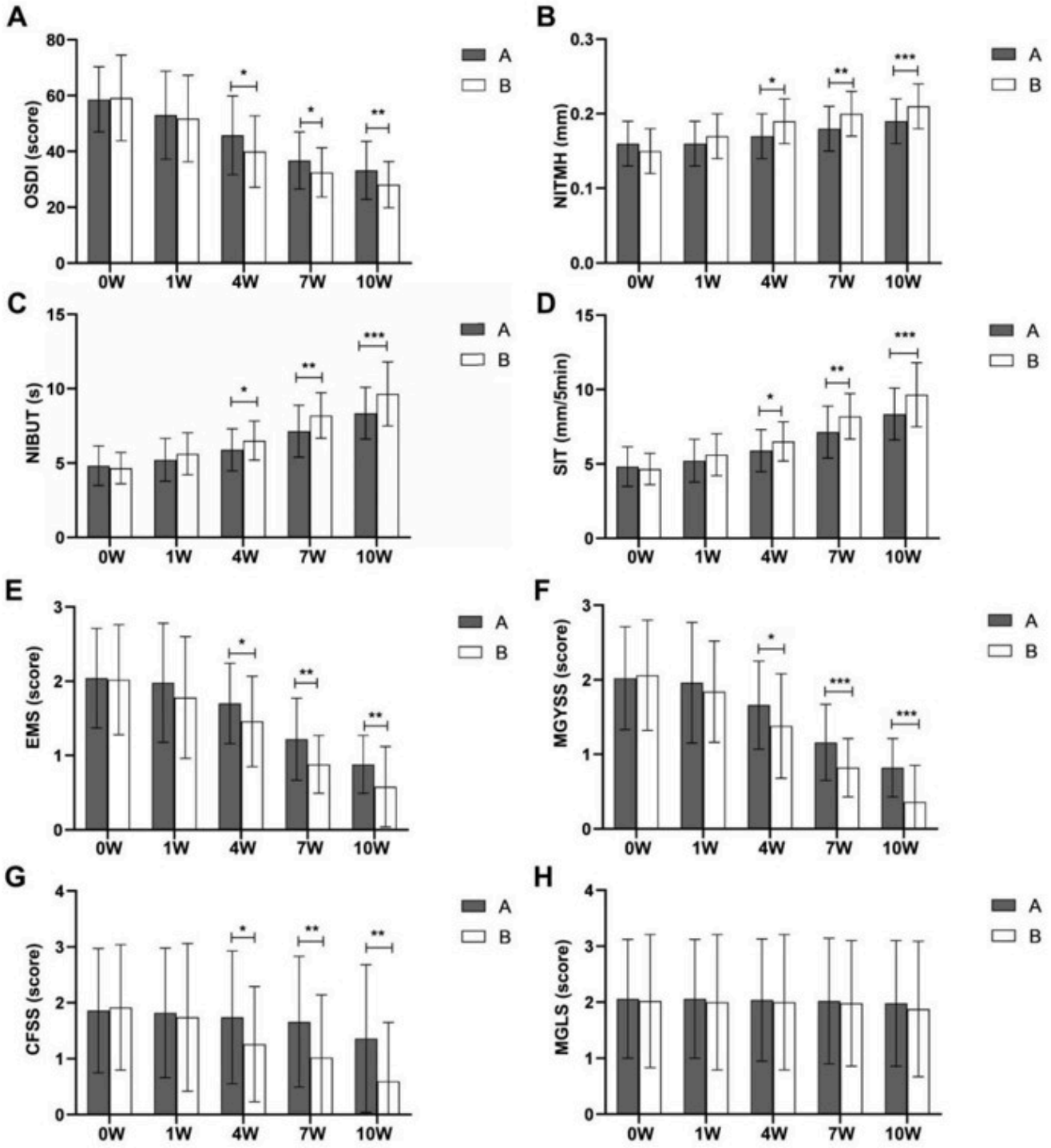


Figure 1

Dynamic variation of each ocular parameter at different follow-up time points in Group A and Group B

Notes: (A:OSDI, B:NITMH, C:NIBUT, D:SIT, E:EMS, F:MGYSS, G:CFSS, H:MGLS)

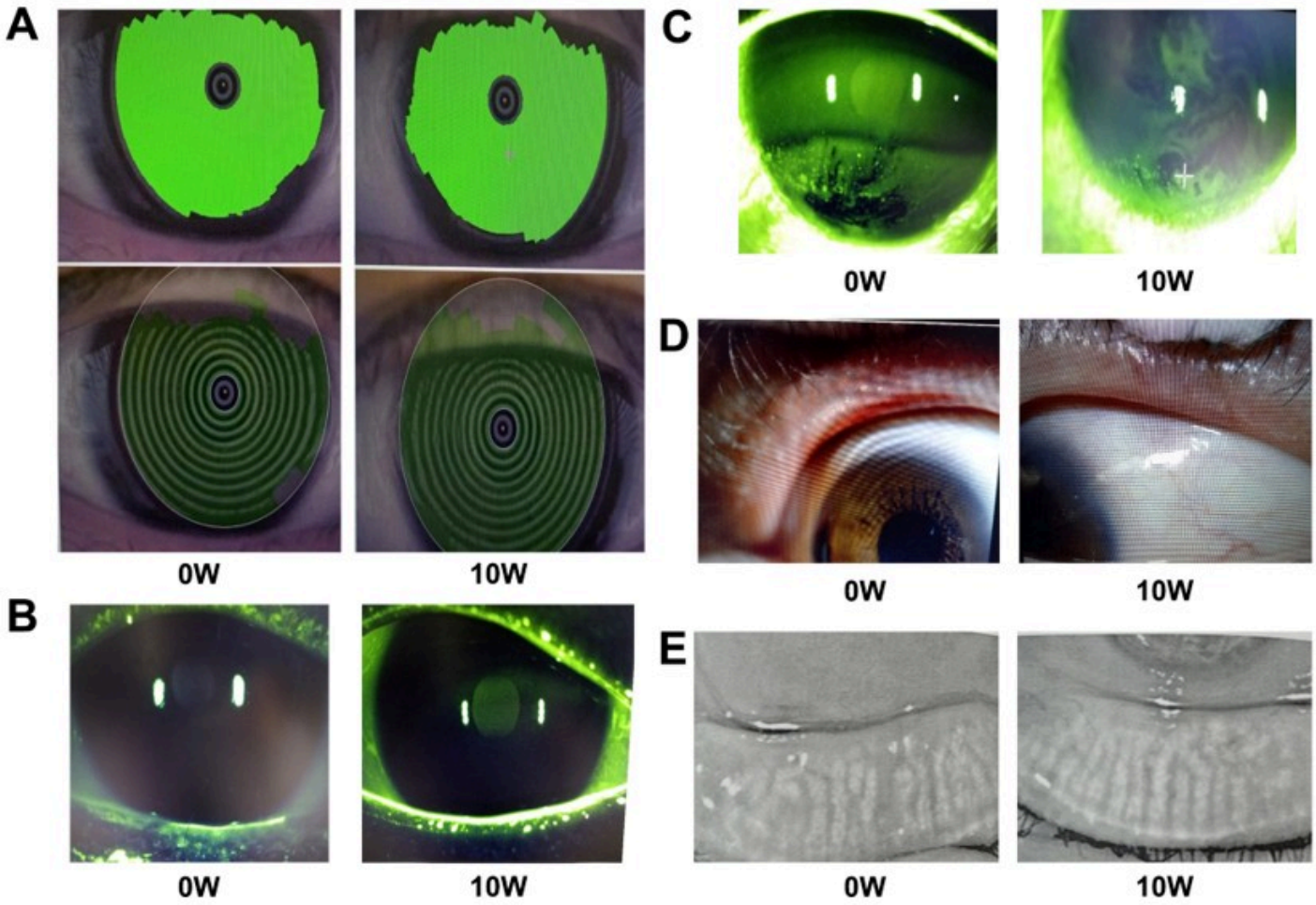


Figure 2

Representative case before and after 10 weeks of combined treatment with IPL, MGE and pharmacotherapy

Notes: (A:NIBUT; B: NITMH; C: CFSS; D: EMS and MGYSS; E: MGLS)