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ORIGINAL RESEARCH

Combination of iLux Photothermal Pulsation Therapy with 0.05% Cyclosporine in the Treatment of Meibomian Gland Dysfunction: A Clinical Study

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Objective: The aim of this study is to investigate the effect of iLux with 0.05% cyclosporine in the treatment of meibomian gland dysfunction.

Methods and Materials: In retrospective analysis, 72 patients of meibomian gland dysfunction were selected and divided into combination groups according to different treatment methods (n=32, iLux + 0.05% cyclosporine ophthalmic fluid) and the conventional group (n=44, 0.05% cyclosporine ophthalmic fluid). Compare the two groups of baseline data and clinical efficacy difference, compare the two groups after treatment eye symptoms, eye surface disease index score change.

Results: Overall response rate of the combined group was higher than the conventional group (P <0.05). Post-treatment, both groups were improved differently (P <0.05), however, in the combined group, ocular symptom score, ocular surface disease index, conjunctival congestion score, corneal fluorescent staining score, meibomian gland (ostium condition score, lipid secretion shape score, deletion score) and interleukin-6, interleukin-1 β were all lower than those in the conventional group, The non-invasive mean tear film break-up time (NIBUTav), non-invasive first tear film break-up time (NIBUTf) and tear meniscus height in the combined group were higher than the conventional group (P <0.05).

Conclusion: ILux meibomian gland photothermal pulsation complex therapy instrument combined with 0.05% cyclosporine ophthalmic solution for the treatment of meibomian gland dysfunction.

Keywords: meibomian gland dysfunction, iLux eyelid gland photothermal pulsatile compound therapy instrument, cyclosporine ophthalmic solution, treatment effect, patients

Introduction

Meibomian gland dysfunction (MGD), as a common and frequently-occurring disease in ophthalmology clinic, with the popularization of electronic products and the accelerated pace of life, the incidence is increasing year by year.[1,2] MGD cannot only lead to eye dryness, foreign body sensation, burning sensation and other uncomfortable symptoms, but also may cause ocular surface damage, affecting the visual quality and the quality of daily life.[3,4] Therefore, exploring safe and effective treatments should relieve patients symptoms and improve prognosis. At present, the clinical treatment of MGD mainly includes physical therapy, drug therapy and surgical therapy and other ways of.[5,6] However, a single treatment approach often struggles to achieve ideal therapeutic effects and is prone to recurrent.[7] In recent years, with the continuous progress of medical technology, iLux composite therapeutic instrument, as a new therapeutic method, has gradually been concerned and favored by clinicians because of its unique therapeutic principle and remarkable curative effect.[8] Through the iLux therapeutic pulse technology, it can effectively promote the dredging and secretion of meibomian glands, thus improving the meibomian gland function. Meanwhile, 0.05% cyclosporine ophthalmic solution,

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as an immunosuppressant, is also widely used in the treatment of MGD. By inhibiting the ocular inflammatory reaction, it reduces the damage and obstruction of the eyelid gland, so as to achieve the therapeutic goal.[9,10]

iLux uses photothermal pulsation technology to penetrate the meibomian glands with yellowish-green light and near-infrared light, selectively heating and melting the blocked meibum, and then discharging the melted meibum under pressure. iLux treatment can significantly improve meibomian gland function, enhance the stability of the tear film, and relieve dry eye symptoms. Cyclosporine, as an immunosuppressant, exerts anti-inflammatory effects by inhibiting T cell activation and reducing the release of inflammatory factors. iLux resolves blockage issues through physical unblocking and restores glandular function. Cyclosporine alleviates inflammatory responses through anti-inflammatory effects. The two respectively target the dual pathological links of blockage and inflammation in MGD, and their formation mechanisms are complementary. The combined use of iLux and cyclosporine can not only immediately improve glandular function but also continuously control inflammation, thereby providing a more comprehensive therapeutic effect. However, there is a lack of systematic studies and reports on the effect and safety of iLux combined with 0.05% cyclosporine ophthalmic solution for MGD. Therefore, the study aims to explore the effect and safety of the iLux eyelid gland photothermal pulsation combined with the ophthalmic solution of 0.05% for MGD, in order to provide more effective treatment options for clinical practice and further improve the quality of life of patients.

Materials and Methods

General Information

This study is a retrospective cohort study. The data are from the prospectively recorded electronic medical records from 2023 to 2024, ensuring the standardization of treatment plans and evaluation processes. For a retrospective analysis, 72 patients with meibomian gland dysfunction admitted to our hospital from January 2023 to June 2024 were selected as the subjects of this study. Inclusion criteria: ① According to relevant clinical diagnostic criteria,[11] meibomian gland dysfunction; ② were first visit; ③ age> 18 years; ④ were both eyes (severe eyes); ⑤ informed about the study and signed the written informed consent; ⑥ complete clinical data. Exclusion criteria: ① with mental illness or cognitive dysfunction; ② with cardiovascular disease; ③ with ocular infection or other diseases that may affect ocular surface homeostasis; ④ history of ocular surgery or trauma before treatment; ⑤ voluntarily withdrew from the investigator. According to different treatment modalities, divided into combination group (n=32, given iLux + 0.05% cyclosporine ophthalmic solution) and conventional group (n=44,0.05% cyclosporine ophthalmic solution). This study has been approved by the Ethics Committee of Aidi Eye Hospital (Approval Number 2024-L-4-23). All patients signed written informed consent forms, in compliance with the requirements of the Declaration of Helsinki.

Study Methods

Routine group: treated with 0.05% cyclosporine ophthalmic fluid treatment. Instill 0.05% cyclosporine ophthalmic solution in both eyes, twice daily for 8 weeks. iLux® photothermal pulsatile procedure: The device maintains eyelid temperature at 42–45°C via dual-pad temperature sensors for 4 minutes, followed by pulsatile pressure (initial 100g, up to 200g based on patient tolerance, 1 pulse/20s) for 4–6 minutes. Treatment endpoints are defined by clear meibomian secretion excretion or a maximum of 3 pressure cycles.

Combination group: using the iLux meibomian gland photothermal pulsation compound therapy instrument + 0.05% cyclosporine ophthalmic fluid treatment. 0.05% cyclosporine is as in the conventional group; iLux photothermal pulsatile procedure: The iLux device consists of a handheld photothermal generator and a single-use patient interface component. Before starting the examination, the patient removed all cosmetics from the eyelids and remained in a straight sitting or slightly tilted position. Equipment preparation, connect the new atypia using the patient interface, insert the internal pad and clip the lid, clip the lid properly, adjust the host position of the eyelid gland to stay away from the eyeball and orbital bone for maximum comfort. Avoid pulling or squeezing the patients eyelid or orbital bone. Heat the eyelids, and slide the heater control switch forward to activate the heating LED, while keeping the eyelids gently fixed in a comfortable position. After the eyelid completion, switch to “dredge mode”. Slowly increase the applied pressure, to discharge the eyelid fat through the orifice of the gland. Re-evaluate patient comfort. If the pressure makes the patient feel

uncomfortable, reduce the intensity. Once melted or clear eyelid fat is excreted, the treatment indicating that the eyelid area is completed, the treatment can be stopped. If the glands do not show melted or clear lid fat, first confirm that the eyelid edge is close to the support arm on the disposable patient interface and stuck between the inside and outer pads. If the patient interface is placed correctly, a maximum of three additional presses may be effective. Re-heating may also improve if the patient remains comfortable and has no signs of excessive eyelid swelling or redness. The combined group received a single iLux treatment within the first week, followed by 0.05% cyclosporine ophthalmic solution for 8 weeks, identical to the conventional group's 8-week monotherapy regimen. All patients were evaluated at the same 8-week endpoint.

Observing Indicators

(1) Baseline data. Comparing the differences in baseline data between the two groups, including age, sex, body quality index, and disease duration.

(2) Clinical efficacy evaluation. After the completion of treatment, the clinical efficacy of both groups was evaluated according to the relevant standard.[12] Among them, all eye symptoms are relieved and disappeared, non-invasive tear film rupture time (NIBUT) is completely recovered, can be judged as recovery; eye symptoms are significantly relieved, NIBUT is slightly lower than normal, which can be judged as significant effect; ocular symptoms are improved, NIBUT has improved, but significantly lower than normal level, can be judged as effective; eye symptoms without any improvement or aggravation, NIBUT has no change than before treatment, can be judged as invalid. Total response rate = recovery rate + line efficiency + response rate. The therapeutic effect is categorized based on two criteria: the degree of symptom improvement and the corresponding ranges of NIBUTav/NIBUTf values. Recovery is defined as the complete resolution of symptoms alongside NIBUTav $\geq$ 10 seconds and NIBUTf $\geq$ 5 seconds. A marked effect indicates symptom relief of at least 70% combined with NIBUTav between 8–10 seconds and NIBUTf between 4–5 seconds. An effective response signifies symptom reduction between 30% and 70%, accompanied by NIBUTav values ranging from 5–8 seconds and NIBUTf values from 2–4 seconds. Finally, an ineffective outcome occurs when symptom relief is below 30% (or symptoms worsen) and NIBUTav is $\leq$5 seconds while NIBUTf is $\leq$2 seconds.

(3) Assessment of ocular symptoms. The degree of ocular symptoms in both groups was assessed by clinical symptom integral and ocular surface disease index[13] before and after treatment. The former includes redness, increased secretion and other symptoms, the higher the score, the less severe the degree of ocular symptoms; the latter is used to evaluate the ocular surface condition, the higher the score, the more severe the ocular surface condition.

(4) Evaluation of indicators related to eye surface function. The functional status of the two groups was assessed at two nodes before and after treatment. Indicators include: ① non-invasive tear film rupture time assessment, Keratograph 5M eye surface comprehensive instrument (company: Oculus, Germany), using infrared light source projection, Placido disk image onto the cornea, and told the patient to blink 2 times. The system switched to the automatic detection mode, and then the patient was instructed to blink again to automatically obtain the non-invasive mean tear film rupture time (NIBUTav) and the non-invasive time of first tear film rupture (NIBUTf). Data was repeated three times and the three measurements were averaged. ② tear meniscus height and conjunctival congestion assessment. Assist the patient to complete the preparation, help the forehead on the frontal band and place the jaw in the bracket. Capture the height of the patient, when in the highest state, the ruler measured the height of the tear river at this time. Then the patient was instructed to keep his eyes open, open the patients eyelids, fully expose the ball conjunctiva, and cover the central round grey ring to cover the cornea. Re-tested three times and averaged. Then, a conjunctival congestion score was performed to assess the degree of conjunctival congestion. ③ Corneal fluorescence staining score. The degree of corneal fluorescence staining in each quadrant of the patient was assessed by slit-lamp cobalt blue light. Among them, no staining recorded 0 points, scattered dots 1 points, dense dots 2 points, and sheet 3 points. Tear meniscus height was measured in millimeters (mm) using the built-in ruler of Keratograph 5M, with the patient gazing straight ahead. Three measurements were taken at the central lower eyelid after a complete blink, and the average value was recorded. Open state (0–3 points: Secretions are easily discharged to the point where they cannot be discharged). Lipid secretion (0–3 points: transparent and clear to paste-like/toothpaste-like) and the degree of glandular loss (0–3 points: no loss to > two-thirds of glandular loss).

(5) Assessment of meibomian gland function status. The functional status of the meibomian gland was evaluated in both groups before and at two nodes after the treatment, including the opening status, lipid secretion properties, and the degree of deletion. Among them, ① evaluated the opening state of the meibomian glands according to the difficulty of excluding the opening secretion. The total score was 3, and the higher the score indicates that the more difficult the secretion is to discharge. ② Evaluation of lipid secretions, in which, transparent, cloudy, cloudy and granular, paste recorded 0,1,2,3, respectively. ③ Record the percentage of missing area of meibomian glands, with no missing, "<1 / 3", "1 / 3~2 / 3" and "> 2 / 3" recorded as 0,1,2 / 3, respectively. Lipid secretion was classified as clear (0), cloudy (1), cloudy with granules (2), or paste-like (3) under slit-lamp microscopy (×16 magnification). Gland dropout was quantified by the percentage of absent glands, with scores assigned as 0 (none), 1 (<1/3), 2 (1/3-2/3), or 3 (>2/3).

(6) The levels of tear inflammatory factors. Tears of 200 μL were collected before and after treatment, and Il-6 and IL-1 β levels were measured by enzyme-linked immunosorbent assay.

(7) Occurrence of adverse reactions. Adverse reactions during treatment, including vision loss, periocular redness, rash, infection, etc.

Statistical Analysis Method

The SPSS 26.0-line statistical analysis was applied. Count data are expressed as n (%), cross-table χ 2 test, non-parametric rank sum test for order rank data; measurement data conforming to normal distribution are expressed as (mean ± standard deviation), independent *t*-test between groups, and paired *t*-test within groups. Based on the effect size of iLux monotherapy in the previous study[14] (Cohen's d = 0.72), with α = 0.05 and β = 0.2 set, it was calculated that at least 30 samples were required for each group. A total of 72 cases were included in this study (32 cases in the combination group and 44 cases in the conventional group), meeting the statistical test efficacy (1−β = 0.85). The results showed that the P value was still < 0.05 after sample size equilibrium, and the conclusion was robust. A difference of P <0.05 was considered to be statistically significant, with all P values two-tailed

Results

Baseline Data

Total response rate = recovery rate + marked efficacy rate + efficacy rate. By comparing the baseline data, gender, age, physical fitness index and disease duration were not significant (P> 0.05). See Table 1.

Clinical Efficacy

After treatment, 32 patients in the combined group, 15 cases (46.9%) achieved recovery (NIBUTav ≥10s), 8 cases (25.0%) showed marked efficacy (NIBUTav 8–10s) and 1 ineffective, and 44 patients recovered 9,16 effective, 9 effective and 10 ineffective. The analysis found that the total response rate of 96.88% was higher than 77.27% in the conventional group, with a statistically significant difference (χ^2=4.276, *P*=0.039<0.05 (Figure 1).

Table 1 Comparison of the Baseline Data Between the Two Groups ($\bar{x} \pm s$)

Group	Example Number	Sex		Age (Year)	Physical Fitness Index (kg/m2)	Course of Disease (Month)
		Male	Female			
Joint group	32	18 (56.25)	14 (43.75)	48.36±8.15	23.51±2.37	17.62±2.05
Conventional group	44	26 (59.09)	18 (40.91)	47.98±7.79	23.18±2.12	18.03±2.34
t/χ2		0.061		0.199	0.635	0.797
P		0.804		0.843	0.528	0.428

Notes: Based on Cohen's d value estimation, the age difference d=0.05 (minimal effect size), the BMI difference d=0.14 (minimal effect size), and the disease duration difference d=0.18 (minimal effect size), suggesting that the impact of baseline differences on the outcome can be ignored. Through the calculation of G*Power software, the test efficacy of this sample size for the primary outcome (total effective rate) was calculated as Power=0.82>0.8, meeting the requirements of statistical power.

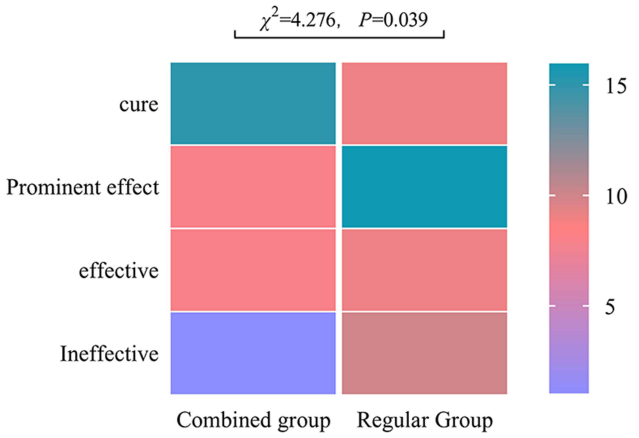

Figure 1 Comparison of the clinical efficacy between the two groups.

Ocular Symptoms

Before treatment, no significant differences were observed in clinical symptom scores or ocular surface disease index (OSDI) scores between the two groups (P > 0.05). After treatment, however, both groups showed improved outcomes. Notably, the combined therapy group demonstrated significantly lower scores compared to the conventional group for both metrics (P < 0.05) (Table 2).

Time of Non-Invasive Tear Film Rupture

Before treatment, the NIBUTav and NIBUTf were not different between the two groups (P> 0.05); after treatment, the above indicators increased (P <0.05), and the combined group was higher than the conventional group (P <0.05) (Table 3).

Table 2 Comparison of Ocular Symptom Levels Between the Two Groups [($\bar{x} \pm s$), Points]

Group	Example Number	Clinical Symptom Integral		t	P	Eye Surface Disease Index		t	P
		Pretherapy	Post-Treatment			Pretherapy	Post-Treatment		
Joint group	32	26.31±3.60	12.81±2.04	17.717	0.000	46.38±6.03	25.31±2.43	21.301	0.000
Conventional group	44	26.02±2.97	16.95±2.31	16.597	0.000	46.11±6.49	30.95±3.70	12.957	0.000
t		0.384	−8.097			0.179	−8.010		
P		0.702	0.000			0.859	0.000		

Table 3 Comparison of the Time of Noninvasive Tear Film Rupture Between the Two Groups [($\bar{x} \pm s$), S]

Group	Example Number	NIBUTav		t	P	NIBUTf		t	P
		Pretherapy	Post-Treatment			Pretherapy	Post-Treatment		
Joint group	32	9.13±2.12	13.03±2.67	6.086	0.000	5.19±1.00	8.59±1.48	11.455	0.000
Conventional group	44	9.34±2.21	11.25±2.81	3.608	0.001	5.36±1.12	7.45±1.30	8.608	0.000
t		−0.428	2.784			−0.707	3.557		
P		0.670	0.007			0.482	0.001		

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Table 4 Comparison of the Tear River Height, Conjunctival Congestion and Corneal Staining Between the Two Groups ($\bar{x} \pm s$)

Metric	Group	n	Pretherapy	Post-Treatment	*t Price*	*P Price*
Tears river height (mm)	Joint group	32	0.18±0.04	0.29±0.06	8.645	0.000
	Conventional group	44	0.20±0.06	0.23±0.05	2.490	0.017
	t	-	−1.749	4.747	-	-
	P	-	0.085	0.000	-	-
Conjunctival congestion score (score)	Joint group	32	2.59±0.50	1.50±0.62	9.659	0.000
	Conventional group	44	2.52±0.55	1.82±0.45	5.880	0.000
	t	-	0.578	−2.469	-	-
	P	-	0.565	0.017	-	-
Corneal fluorescent staining score (score)	Joint group	32	2.25±0.57	1.13±0.34	9.644	0.000
	Conventional group	44	2.20±0.63	1.48±0.51	5.530	0.000
	t	-	0.323	−3.647	-	-
	P	-	0.748	0.000	-	-

Tear Meniscus Height, Conjunctival Congestion, and Corneal Staining Degree

Before treatment, there was no difference in tear height, conjunctival congestion score and corneal fluorescent staining score between the two groups (P> 0.05); after treatment, the tear height increased compared with the level before treatment (P <0.05), the conjunctival congestion score and corneal fluorescent staining score decreased compared with the pretreatment level (P <0.05), and the tear height was higher than the conventional group, and the conjunctival congestion score and corneal fluorescent staining score in the combined group were lower than the conventional group (P <0.05) (Table 4).

Meibomian Gland Functional Status

Before treatment, there was no difference in tear height, conjunctival congestion score and corneal fluorescent staining score between the two groups (P> 0.05); after treatment, the tear height increased compared with the level before treatment (P <0.05), the conjunctival congestion score and corneal fluorescent staining score decreased compared with the pretreatment level (P <0.05), and the tear height was higher than the conventional group, and the conjunctival congestion score and corneal fluorescent staining score in the combined group were lower than the conventional group (P <0.05) (Table 5).

Table 5 Comparison of Functional Status Between the Two Groups [($\bar{x} \pm s$), s]

Metric	Group	n	Pretherapy	Post-treatment	*t Price*	*P Price*
Open state	Joint group	32	1.81±0.47	0.72±0.46	13.290	0.000
	Conventional group	44	1.77±0.42	0.95±0.21	13.910	0.000
	t	-	0.385	−2.717	-	-
	P	-	0.701	0.010	-	-
Dissertion shape	Joint group	32	1.47±0.51	0.66±0.48	9.760	0.000
	Conventional group	44	1.39±0.49	1.02±0.26	4.957	0.000
	t	-	0.711	−3.895	-	-
	P	-	0.479	0.000	-	-
Deletion degree	Joint group	32	1.78±0.61	0.72±0.46	13.806	0.000
	Conventional group	44	1.75±0.58	1.02±0.34	8.243	0.000
	t	-	0.228	−3.178	-	-
	P	-	0.820	0.002	-	-

Table 6 Comparison of Tear Inflammatory Levels Between the Two Groups [($\bar{x} \pm s$), ng/ml]

Group	Example Number	IL-6 (pg/mL)		t	P	IL-1β (pg/mL)		t	P
		Pretherapy	Post-Treatment			Pretherapy	Post-Treatment		
Joint group	32	76.13±11.36	29.35±5.21	19.577	0.000	65.23±13.02	26.37±6.14	15.450	0.000
Conventional group	44	75.85±12.62	38.27±6.85	17.722	0.000	64.65±14.43	34.42±7.31	11.454	0.000
t		0.100	−6.177			0.180	−5.063		
P		*0.921*	*0.000*			*0.858*	*0.000*		

Tear Inflammatory Levels

Before treatment, the NIBUTav and NIBUTf were not different between the two groups (P> 0.05); after treatment, the above indicators increased (P <0.05), and the combined group was higher than the conventional group (P <0.05) (Table 6).

Adverse Reactions

In the combined group, 32 patients had 1 case of vision loss and 1 case of periocular redness and swelling, the total incidence was 6.25%; In the conventional group, 44 patients had 1 case of vision loss, 2 cases of periocular redness and swelling, 1 case of rash and 1 case of infection, and the total incidence was 9.09%. The comparison of the two groups, the total incidence of adverse reactions between the two groups was not statistically significant (χ^2=0.129, P=0.719>0.05) (Figure 2).

Discussion

In this study, the significant reduction of inflammatory factors and the improvement of glandular function were observed in the combined group. The synergistic effect of Lux and cyclosporine may stem from dual-pathway regulation. The iLux® system effectively melts the blockage of the meibomian glands through thermal mechanical pulses, promoting normal lipid secretion and thus improving symptoms in patients with meibomian gland dysfunction (MGD). In contrast, 0.05% cyclosporine blocks T-cell activation reducing the release of pro-inflammatory cytokines such as IL-6 and IL-1β thereby inhibiting ocular surface inflammation. These two treatments address the obstructive and inflammatory aspects of MGD from a physical and immunomodulatory perspective, respectively, providing effective solutions. In a study, the iLux® system was compared with mechanical meibomian gland expression (MMGE). The results showed that iLux® significantly outperformed MMGE in improving symptoms and signs in patients with meibomian gland disease (MGD). During a one-year follow-up, the iLux® treatment group showed significant improvements in meibomian gland score (MGS), non-invasive tear film break-up time (NI-BUT), and ocular surface disease index (OSDI) scores, with no adverse events reported.[14] This indicates that the iLux® system is not only effective in the short term but also demonstrates good safety and effectiveness in long-term management of MGD.

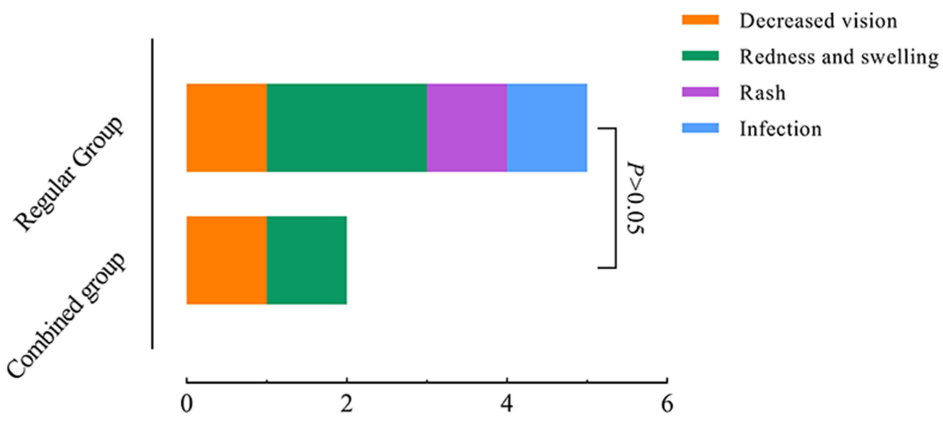

Figure 2 Comparison of the occurrence of adverse reactions between the two groups.

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In the study of drug synergistic mechanisms, cyclosporine A (CsA), a calcineurin inhibitor, has been shown to significantly enhance the activity of certain antifungal drugs. For example, the combination of CsA and fluconazole (FLC) demonstrates a synergistic effect in inhibiting the formation of Candida albicans biofilms and enhancing their sensitivity to FLC.[15] This synergy involves suppressing the expression of biofilm-related genes and resistance genes, reducing cellular surface hydrophobicity, and increasing intracellular calcium levels. Furthermore, the combination of CsA and Remdesivir has demonstrated a synergistic inhibitory effect on human coronaviruses OC43 and SARS-CoV-2[16.] Research indicates that these two drugs inhibit viral replication through distinct mechanisms, and their combined use results in a more potent inhibitory effect. This synergy may be attributed to their ability to reduce the production of virus-induced cytokines, such as IL-6.

The combined treatment's superior efficacy (96.88% response rate, Figure 1) likely stems from complementary actions: iLux's photothermal pulsation (42–45°C, 4 minutes) melts inspissated meibum, while 0.05% cyclosporine suppresses T-cell-mediated inflammation. This dual approach addresses both the obstructive (meibomian gland blockage) and inflammatory (cytokine release) components of MGD, as reflected in the combined group's 61% reduction in IL-6 levels, significantly greater than the conventional group's 49% reduction. The photothermal pulsation technology of iLux has shown significant effects in regulating cellular metabolism. By utilizing the photothermal effect, iLux can effectively melt and reshape the metabolic network of cells, thereby influencing their function and state. This process reduces the density of cellular metabolism, promoting the recovery of normal cell function and health. Additionally, 0.05% cyclosporine, an immunosuppressant, can effectively inhibit T-cell-mediated inflammatory responses. Cyclosporine reduces the intensity of inflammatory reactions by inhibiting the activation and proliferation of T cells, thereby decreasing the release of inflammatory factors. In chronic infections, the function and regulation of T cells are crucial for controlling pathogen replication and reducing inflammatory damage.[17] Research indicates that calcium ion channels and their activators play a significant role in T cell-mediated immune regulation. For instance, STIM1 is essential for T cell immune regulation during chronic Mycobacterium tuberculosis infection. T cells lacking STIM1 exhibit increased IFN-γ production during the chronic infection phase,[18] which is associated with elevated levels of IL-12 and IL-18. However, this excessive immune response can lead to an increase in lymphocytes and excessive inflammation in the lungs, thereby exacerbating the condition.[19] Furthermore, the role of microglia in neuroinflammation has gained attention. CHTOP, a novel regulator, promotes neuroinflammation mediated by microglia by regulating the transcription of genes related to inflammation and cellular metabolism.[20] Studies have shown that knocking down CHTOP can reduce the expression of pro-inflammatory cytokines and improve neuronal survival, indicating the significant role of CHTOP in inflammation regulation.

This study showed that the combination group was better than the conventional group ($P < 0.05$). This result indicates that the combination of iLux gland photothermal pulsation compound therapy instrument and 0.05% cyclosporine ophthalmic solution has a synergistic effect in the treatment of meibomian gland dysfunction, which can improve the symptoms and improve the treatment effect. The ocular symptom score is an important indicator to measure the severity of eye discomfort symptoms in patients, and the ocular surface disease index is a comprehensive indicator to reflect the health status of the ocular surface.[21] After treatment in this study, both groups showed significant improvement in ocular symptom score and ocular surface disease index, which reflects the efficacy of both treatments for meibomian gland dysfunction. However, it is noteworthy that the combined group improved significantly better in the ocular symptom integral and the ocular surface disease index than in the conventional group. The possible reason for this is that the iLux eyelid gland photothermal pulse composite therapeutic device includes the handheld eyelid gland pulse generator and the disposable patient interface. The single-use patient interface includes the internal and outer pads used for insertion around the patients lower or upper eyelid. The device can provide heating and pressurization to clear the blockage of the meibomian gland. Use the light energy emitted from the LED inside the host machine of the eyelid gland to heat the target eyelid tissue for.[22] Light travels through the transparent pad and is absorbed by the chromophore inside the tissue. Monitor the temperature sensors in the inner and outer pads to ensure that the eyelid temperature is kept within the optimum range to melt the blockage of the meibomian gland orifice. After the blockage melts, press the "pressure control" button to compress the eyelid between the inner pad and the outer pad, allowing the molten eyelid fat to be discharged through the hole. The iLux meibomian gland photothermal pulsation compound therapy instrument penetrates

into the meibomian gland through unique technology, promotes dredging and secretion, improves dysfunction, while promoting blood circulation in the eyes and reducing inflammatory response.[18,23] 0.05% cyclosporine ophthalmic solution, as an immunosuppressive agent, can inhibit the ocular inflammatory response, reduce the release of inflammatory factors, reduce tissue damage, and promote repair and regeneration. When the two are combined, physical therapy promotes the recovery of meibomian gland function, medical treatment reduces inflammation, and the synergistic effect significantly improves the eyeSymptoms of the.[24] After treatment, the conjunctival congestion score and corneal fluorescence staining score in the combined group were lower than the conventional group, and the NIBUTav, NIBUTf and tear meniscus height in the combined group were higher than the conventional group ($P < 0.05$), indicating that the combined treatment regimen was better than the conventional treatment regimen in improving ocular symptoms and promoting ocular health recovery. Conjunctival congestion is often caused by ocular inflammation or stimulation. The iLux therapeutic device can reduce ocular inflammation, promote circulation, and reduce conjunctival congestion of.[25,26] The 0.05% cyclosporine ophthalmic solution also had anti-inflammatory effects to further alleviate the congested.[27] Corneal fluorescence staining scores showed that the iLux therapeutic apparatus improved meibomian gland function, enhanced tear film stability, and reduced corneal epithelial damage. NIBUTav, NIBUTf and tear meniscus height show that iLux improves stability by enhancing the lipid layer of tear film, while cyclosporine ophthalmic solution reduces inflammation, reduces tear evaporation and increases secretion. The two work together to significantly improve ocular symptoms and promote healthy recovery of.[28] Furthermore, after treatment, the IL-6 and IL-1 β levels were significantly lower in the combination group than those in the conventional group ($P < 0.05$). This result suggests that the combination treatment regimen is better to the conventional treatment in reducing ocular inflammatory response and has a more significant anti-inflammatory effect. Cyclosporine at 0.05% inhibited T cell activation, reduced inflammatory factors such as IL-6 and IL-1 β, and reduced ocular inflammation. The iLux therapeutic apparatus penetrates into the meibomian gland to promote dredging and secretion, improve dysfunction, while stimulating tissues, promote circulation and lymphatic reflux, accelerate the metabolism of inflammatory factors, and reduce ocular inflammation.[29]

This study has some limitations. The observed effective rate of the combined group was 19.61% higher (96.88% vs 77.27%). Due to the retrospective design, it should be interpreted with caution. Although the sensitivity analysis (ANCOVA/PSM) supports robustness, there is still the possibility that confounding factors have not been measured. Unequal sample sizes (32 vs 44) and single-center Settings limited the universality of the results. The 8-week follow-up period is relatively short and cannot assess the long-term efficacy. The absence of a fake iLux group prevented the exclusion of the placebo effect. These limitations emphasize the need for prospective, multicenter randomized controlled trials, larger sample sizes and longer follow-ups to confirm our findings.

In conclusion, our findings suggest that iLux combined with 0.05% cyclosporine eye drops may be an effective approach for MGD, as evidenced by improved meibomian gland function, ocular surface parameters, and reduced inflammation (Tables 3–6). However, these results are limited by the retrospective design and require validation in prospective RCTs with balanced sample sizes and extended follow-up.

Ethics Approval and Informed Consent

This study has been approved by the Ethics Committee of Aidi Eye Hospital (Approval Number 2024-L-4-23). All patients signed written informed consent.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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