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ORIGINAL RESEARCH

Age-Related Differences in the Efficacy of Intense Pulsed Light Therapy for Meibomian Gland Dysfunction in Women

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Purpose: Aging and hormonal factors influence meibomian gland dysfunction (MGD), which can be treated by intense pulsed light (IPL) therapy. However, the influence of age on treatment response remains unclear. This study aimed to investigate the impact of aging on the outcomes of IPL therapy among female patients with MGD.

Patients and Methods: Sixty-eight eyes of female patients who underwent four IPL treatment sessions were included. Patients were divided into two age groups: <50 years (39.5 ± 10.2 years, n = 30) and ≥50 years (72.5 ± 9.49 years, n = 38). Parameters assessed before and after IPL included corneal and conjunctival staining score, fluorescein tear film break-up time (FBUT), lipid layer thickness (LLT), subjective symptoms (Standard Patient Evaluation of Eye Dryness [SPEED] score), and meibomian gland parameters (meibum quality, expressibility, and meiboscore). Statistical analyses were performed using the Mann–Whitney U and Wilcoxon signed-rank tests; $p < 0.05$ indicated statistical significance.

Results: At baseline, the younger group had lower LLT ($p < 0.01$) and poorer expressibility ($p = 0.049$) than did the older group, who showed worse corneal and conjunctival staining score ($p = 0.04$) and meiboscore ($p < 0.01$). After treatment, the younger group exhibited significant improvements in FBUT, LLT, meibum quality, expressibility, meiboscore, and SPEED scores, whereas the older group showed significant improvement in corneal and conjunctival staining scores, FBUT, expressibility, and SPEED scores. Between-group comparisons showed greater improvements in meibum quality and expressibility in the younger group (both $p < 0.01$), while improvement in corneal and conjunctival staining score was greater in the older group ($p = 0.02$).

Conclusion: IPL therapy improved MGD-related signs and symptoms in women of all ages. The observed age-related differences in the most responsive parameters suggest that age affects the therapeutic profile of IPL. These results may help guide age-appropriate MGD management.

Keywords: meibomian gland dysfunction, intense pulsed light, lipid layer thickness, standard patient evaluation of eye dryness score, age-related differences

Introduction

Meibomian gland dysfunction (MGD) is a leading cause of evaporative dry eye and is characterized by diffuse abnormalities in the quality and quantity of meibomian gland secretions, resulting in tear film instability, visual disturbance, and reduced quality of life.[1] The underlying pathophysiology involves chronic inflammatory changes accompanied by ductal epithelial keratinization and altered meibum secretion, which have been systematically defined by the International Workshop on Meibomian Gland Dysfunction.[2]

Population-based studies in Japan have demonstrated that the prevalence of MGD increases with age, from approximately 5% in the 30s to 32% in the 50s, 50% in the 70s, and up to 63% in the 80s.[3] Globally, a systematic review and meta-analysis estimated the overall prevalence to be approximately 35–36%.[4] With the aging population and wider availability of diagnostic devices for dry eye disease, the number of patients with MGD is expected to continue

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rising. Current clinical practice guidelines recommend a stepwise approach, beginning with home-based care, such as warm compresses and lid hygiene, and escalating to in-office procedures as necessary.[1]

Intense pulsed light (IPL) therapy, initially developed for dermatologic indications such as rosacea and vascular lesions,[5,6] has been adapted for MGD based on the involvement of eyelid telangiectasia and periocular inflammation. Clinical studies have reported that IPL therapy improves tear film stability, subjective symptoms, and ocular surface and meibomian gland findings in patients with MGD.[7,8] In addition, reductions in tear inflammatory cytokine levels following IPL therapy have been demonstrated,[9] and systematic reviews and meta-analyses have further supported its therapeutic efficacy.[10–12]

However, few studies have systematically investigated which clinical parameters and symptoms exhibit more pronounced changes between different age groups under a standardized IPL protocol. The underlying disease mechanisms may also differ by life stage: in younger individuals, contact lens wear and cosmetic residue may contribute to meibomian gland orifice obstruction and increased meibum viscosity,[13–15] whereas in older women, age-related gland atrophy and postmenopausal hormonal changes are major etiologic factors.[16,17] Based on these considerations, the present study aimed to compare pre- and post-treatment changes in young and older female patients with MGD who were treated with a standardized four-session IPL protocol and to identify the parameters that tend to show relatively greater improvement depending on age. The results are expected to be useful for designing age-appropriate strategies to optimize MGD management.

Materials and Methods

Study Design and Participants

This retrospective observational study included female patients diagnosed with MGD who completed four sessions of IPL therapy at Chukyo Eye Clinic between April 2023 and December 2024. A total of 68 eyes were analyzed. Patients were stratified into two age groups: those younger than 50 years (U group; mean age, 39.5 ± 10.2 years; n = 30) and those aged 50 years or older (O group; mean age, 72.5 ± 9.5 years; n = 38). The age threshold of 50 years was selected to represent a clinically meaningful transition phase that approximately corresponds to the menopausal phase in women, which is characterized by substantial hormonal changes that influence meibomian gland morphology and secretory function.

Exclusion criteria included pregnancy or lactation, photosensitivity, keloid predisposition, a history of epilepsy, or any condition deemed unsuitable for IPL therapy by the attending physician. This study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Chukyo Eye Clinic (approval number: 20250328092). Because this study was retrospective, we adopted an opt-out approach approved by the ethics committee of Chukyo Eye Clinic instead of obtaining written informed consent.

Diagnosis and Evaluation Parameters

The primary outcome measures were ocular surface epithelial staining, meibomian gland function (meibum quality, expressibility, and meiboscore), lipid layer thickness (LLT), and subjective symptoms.

The diagnosis of MGD was based on the Japanese MGD Clinical Practice Guidelines,[1] which define MGD as the presence of ocular discomfort (such as foreign body sensation or tearing) with abnormal lid margin morphology and qualitative or quantitative abnormalities in meibomian gland secretion. All evaluations were performed before treatment and one month after the fourth IPL session by the same corneal specialist (S.G.) using slit-lamp biomicroscopy. Corneal and conjunctival staining was graded using the modified Oxford scale.[18,19] Meibomian gland function was assessed by grading meibum quality (0 = clear, 1 = cloudy, 2 = cloudy with particulate matter, 3 = toothpaste-like) and expressibility (1 = easy, 2 = moderate, 3 = hard).[19] Meibomian gland dropout was evaluated using the meiboscore obtained from lower-lid meibography (0 = no loss; 1 = <1/3 loss; 2 = 1/3–2/3 loss; 3 = >2/3 loss).[20] LLT was measured using a non-contact interferometric method with the IDRA® ocular surface analyzer (SBM Sistemi Srl, Trino, Italy). Subjective symptoms were evaluated using the Standard Patient Evaluation of Eye Dryness (SPEED) questionnaire.[21]

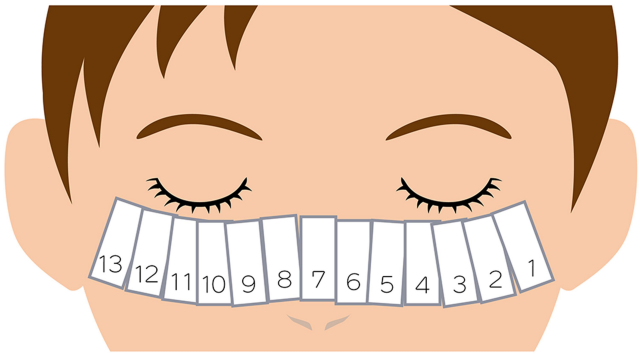

Figure 1 Clinical protocol for intense pulsed light therapy showing the treatment area and sequence.
Abbreviation: MGD, meibomian gland dysfunction.

IPL Protocol and Adjunctive Care

IPL treatment was performed using the M22 system (Lumenis Be Ltd., Yokneam, Israel) equipped with a 590-nm filter and a fluence of 12 J/cm^2. The treatment sequence consisted of 13 shots per pass applied vertically to the following areas: temple → cheek → below lower eyelid → nasal area → contralateral temple (Figure 1). Two passes were administered to the skin surface, followed immediately by in-office meibomian gland expression. Each IPL session was defined as one treatment set, and four sessions were performed at approximately 4-week intervals, according to the Toyos protocol.[8]

All patients were receiving IPL therapy for the first time at our institution. At baseline, the patients may have been using topical treatments for meibomian gland dysfunction as part of routine clinical care. During the study period, these concomitant topical treatments were continued as clinically indicated and were not considered part of the primary intervention in this study. Therefore, they were not standardized or systematically recorded for the purpose of this analysis.

All patients were instructed to continue standardized home-based care, including warm compresses and lid hygiene, which are also recommended as first-line interventions (Step 1) in accordance with the Tear Film and Ocular Surface Society Dry Eye Workshop II (TFOS DEWS II) report and the updated TFOS DEWS III Management and Therapy report.[22–24] Although patients were expected to follow these instructions, adherence to home-based care was not objectively assessed.

Given the study design, residual confounding related to baseline disease severity and concomitant treatments could not be entirely excluded.

Statistical Analysis

Normality of data distribution was assessed using the Shapiro–Wilk test, and non-parametric tests were applied accordingly. Between-group comparisons were performed using the Mann–Whitney *U*-test, and within-group pre- and post-treatment comparisons were performed using the Wilcoxon signed-rank test. A two-tailed p value of <0.05 indicated statistical significance. All analyses were conducted using EZR version 1.68 (Jichi Medical University, Tochigi, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). EZR is a modified version of R Commander designed to provide statistical functions frequently used in biostatistics.[25]

Results

Baseline Characteristics

Among the 68 eyes included in the analysis, 30 were in the U group and 38 in the O group. The O group was significantly older ($p < 0.01$). At baseline, the U group showed lower LLT and poorer meibum expressibility ($p = 0.049$), whereas the O group exhibited worse corneal and conjunctival staining score and higher meiboscore ($p = 0.04$ and $p < 0.01$, respectively). No significant between-group differences were observed in FBUT, meibum quality, or SPEED score (Table 1).

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Table 1 Baseline Characteristics of Female Patients with Meibomian Gland Dysfunction Before Intense Pulsed Light

	Under 50 years Group (n=30)	Over 50 years Group (n=38)	*p*-value
Age (years)	39.5 ± 10.2	72.5 ± 9.5	<0.01*
Corneal and conjunctival staining score	0.13 ± 0.35	0.74 ± 1.18	0.04*
FBUT (s)	3.47 ± 2.23	3.68 ± 1.22	0.95
Meibum quality	2.03 ± 0.41	1.87 ± 0.41	0.11
Meibom expressibility	1.90 ± 0.80	1.53 ± 0.69	0.049*
Meiboscore	1.03 ± 0.61	1.58 ± 0.55	<0.01*
LLT (nm)	57.2 ± 15.7	68.0 ± 15.2	<0.01*
SPEED Score	9.2 ± 4.96	12.0 ± 6.44	0.07

Notes: Values are presented as mean ± standard deviation unless otherwise indicated. *p < 0.05, Mann–Whitney *U*-test.
Abbreviations: FBUT, fluorescein tear film break-up time; s, seconds; LLT, lipid layer thickness; SPEED, Standard Patient Evaluation of Eye Dryness.

Tear Film Parameters

Corneal and conjunctival staining score decreased from 0.13 to 0.03 in the U group ($p = 0.15$) and from 0.74 to 0.21 in the O group ($p < 0.01$) (Table 2 and Figure 2). The change in corneal and conjunctival staining score (Δ Corneal and conjunctival staining score) was significantly greater in the O group (Table 3; −0.52 vs −0.10, $p = 0.02$). FBUT increased significantly in both groups (Table 2 and Figure 2; U group: 3.47 → 5.17 s, $p < 0.01$; O group: 3.68 → 5.05 s, $p < 0.01$), with no significant difference in the magnitude of improvement between groups (Table 3; +1.70 s vs +1.37 s, $p = 0.37$). LLT significantly increased in the U group (Table 2 and Figure 2; 57.2 → 64.5 nm, $p = 0.04$) and showed a non-significant upward trend in the O group (Table 2 and Figure 2; 68.0 → 70.5 nm, $p = 0.23$). The change in LLT (ΔLLT) did not differ significantly between groups (Table 3; +7.30 nm vs +2.47 nm, $p = 0.28$).

Table 2 Pre- and Post-Treatment Changes in Ocular Surface, Meibomian Gland, and Tear Film Parameters by Age Group After Intense Pulsed Light

	Under 50 Years Group (n=30)			Over 50 Years Group (n=38)		
	Pre/IPL	Post/IPL	p value	Pre/IPL	Post/IPL	*p*-value
Corneal and conjunctival staining score	0.13 ± 0.35	0.03 ± 0.18	0.15	0.74 ± 1.18	0.21 ± 0.62	<0.01*
FBUT (s)	3.47 ± 1.22	5.17 ± 1.02	<0.01*	3.68 ± 2.23	5.05 ± 1.63	<0.01*
LLT (nm)	57.2 ± 15.7	64.5 ± 17.6	0.04*	68.0 ± 15.2	70.5 ± 13.9	0.23
Meibum quality	2.03 ± 0.41	1.17 ± 0.59	<0.01*	1.87 ± 0.41	1.74 ± 0.60	0.30
Meibum expressibility	1.90 ± 0.80	1.10 ± 0.25	<0.01*	1.53 ± 0.69	1.29 ± 0.46	0.02*
Meiboscore	1.03 ± 0.61	0.73 ± 0.58	<0.01*	1.58 ± 0.55	1.42 ± 0.68	0.14
SPEED score	9.2 ± 4.96	4.74 ± 4.44	<0.01*	12.0 ± 6.44	5.14 ± 3.59	<0.01*

Notes: Values are presented as mean ± standard deviation unless otherwise indicated. *p < 0.05, Mann–Whitney *U*-test.
Abbreviations: FBUT, fluorescein tear film break-up time; s, seconds; LLT, lipid layer thickness; SPEED, Standard Patient Evaluation of Eye Dryness.

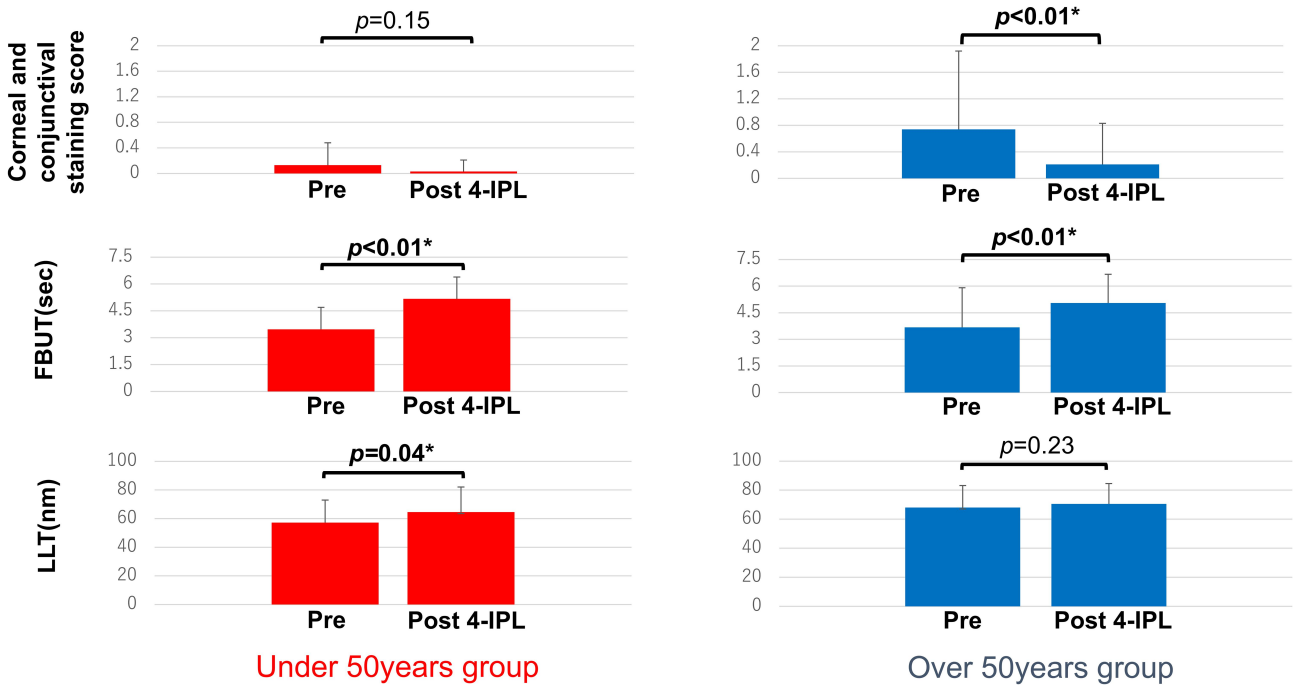

Figure 2 Changes in corneal and conjunctival staining score, fluorescein tear film break-up time, and lipid layer thickness. Patients are stratified into two age groups: those younger than 50 years (n = 30) and those aged 50 years or older (n = 38). Data are presented as mean ± standard deviation. Error bars represent standard deviations. Within-group comparisons have been performed using the Wilcoxon signed-rank test. *p < 0.05; Bold values indicate statistically significant changes within each group.

Changes in Meibomian Gland Function and Morphology

Meibum quality improved significantly in the U group (Table 2 and Figure 3; 2.03 → 1.17, $p < 0.01$), whereas the O group showed a non-significant numerical improvement (Table 2 and Figure 3; 1.87 → 1.74, $p = 0.30$). Meibum expressibility improved in both groups (Table 2 and Figure 3; U group: 1.90 → 1.07, $p < 0.01$; O group: 1.53 → 1.29, $p = 0.02$).

Table 3 Comparison of Age-Related Differences in Changes in Ocular Surface, Meibomian Gland, and Tear Film Parameters After Intense Pulsed Light

Outcome	Under 50 years Group (n=30)	Over 50 years Group (n=38)	*p*-value
	ΔPost/IPL-Pre/IPL		
Corneal and conjunctival staining score	Δ−0.10	Δ−0.52	0.02*
FBUT (s)	Δ+1.70	Δ+1.37	0.37
LLT (nm)	Δ+7.30	Δ+2.47	0.28
Meibum quality	Δ−0.87	Δ−0.13	<0.01*
Meibum expressibility	Δ−0.83	Δ−0.24	<0.01*
Meiboscore	Δ−0.30	Δ−0.16	0.39
SPEED score	Δ−4.44	Δ−6.89	0.19

Note: *p < 0.05, Mann–Whitney *U*-test.
Abbreviations: FBUT, fluorescein tear film break-up time; s, seconds; LLT, lipid layer thickness; SPEED, Standard Patient Evaluation of Eye Dryness.

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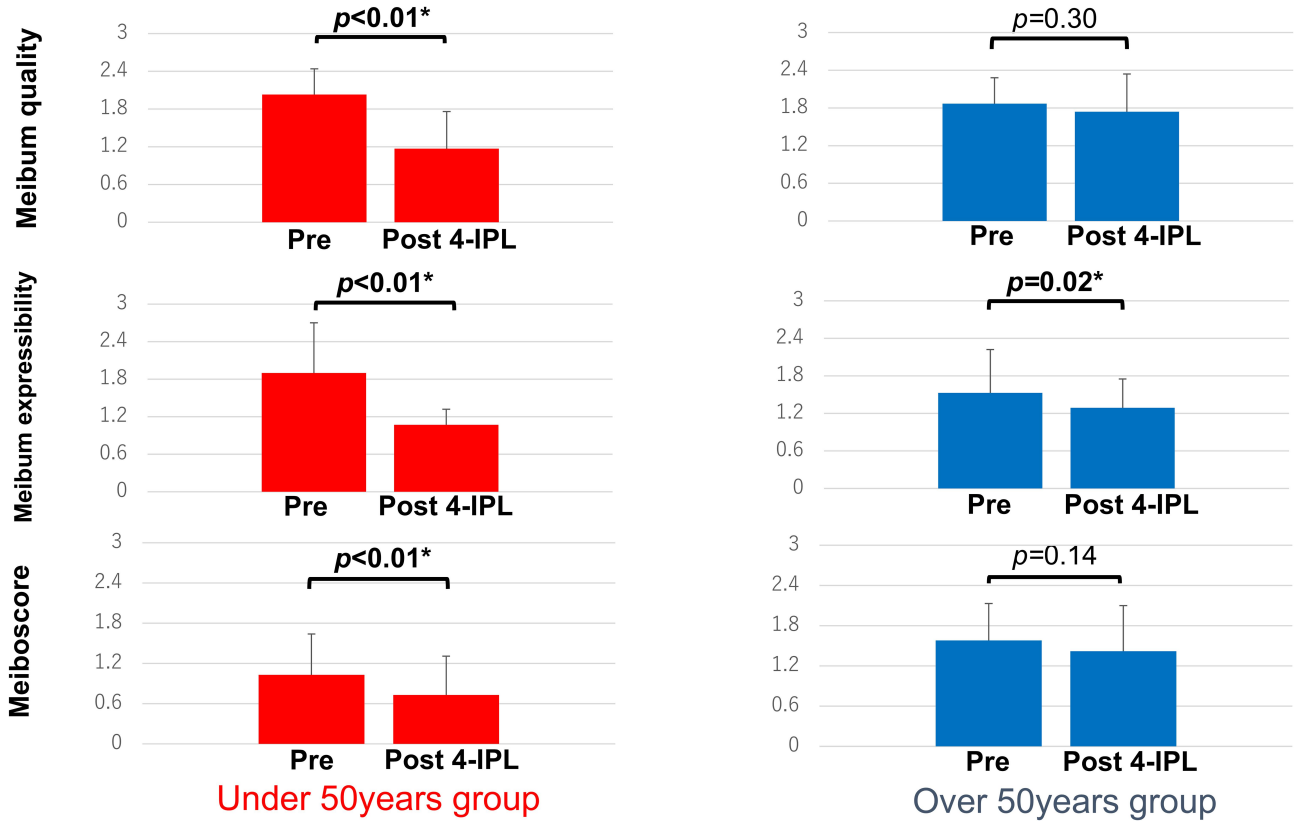

Figure 3 Changes in meibum quality, expressibility, and meiboscore. Patients are stratified into two age groups: those younger than 50 years (n = 30) and those aged 50 years or older (n = 38). Data are presented as mean ± standard deviation. Error bars represent standard deviations. Within-group comparisons have been performed using the Wilcoxon signed-rank test. *p < 0.05; Bold values indicate statistically significant changes within each group.

Between-group comparison of change magnitude showed greater improvement in the U group than in the O group for both meibum quality (Δ−0.87 vs −0.13, $p < 0.01$) and expressibility (Δ−0.83 vs −0.24, $p < 0.01$). Meiboscore decreased significantly in the U group (Table 2 and Figure 3; 1.03 → 0.73, $p < 0.01$) and showed a non-significant decrease in the O group (Table 2 and Figure 3; 1.58 → 1.42, $p = 0.14$). The change in meiboscore did not differ significantly between the U and O groups (Table 3; Δ−0.30 vs −0.16, $p = 0.39$).

Changes in Subjective Symptoms

SPEED scores improved significantly in both groups (Table 2 and Figure 4; U group: 9.2 → 4.74; O group: 12.0 → 5.14; both $p < 0.01$). No significant difference was found in the change magnitude between the U and O groups (Table 3; Δ−4.44 vs −6.89, p = 0.19).

Safety

No intraoperative or postoperative complications were observed in any patients during or after the IPL treatment.

Discussion

This study applied a standardized four-session IPL protocol and examined pre- and post-treatment changes in female patients with MGD, stratified by age. The main findings were as follows: (1) FBUT significantly increased and SPEED scores decreased consistently in both age groups; (2) improvements in LLT and meibum function (quality and expressibility) were relatively greater in the U group than in the O group, although the O group also showed a significant improvement in expressibility; (3) corneal and conjunctival staining score improved more prominently in the O group than in the U group, while a decreasing trend was also observed in the U group. Furthermore, inter-

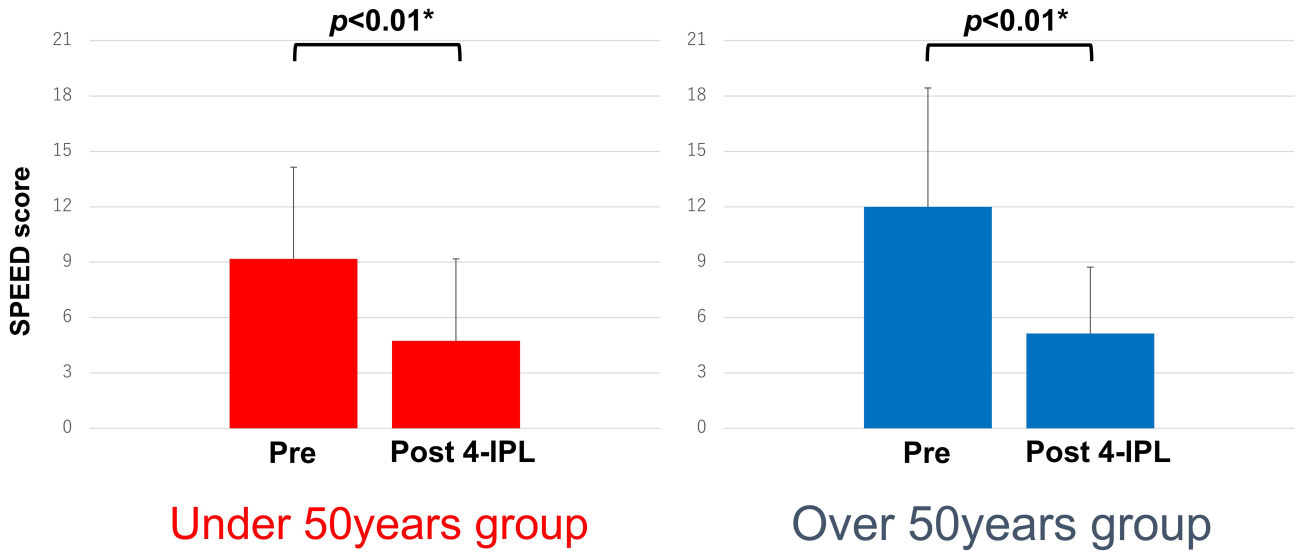

Figure 4 Changes in Standard Patient Evaluation of Eye Dryness score. Patients are stratified into two age groups: those younger than 50 years (n = 30) and those aged 50 years or older (n = 38). Data are presented as mean ± standard deviation. Error bars represent standard deviations. Within-group comparisons have been performed using the Wilcoxon signed-rank test. *p < 0.05; Bold values indicate statistically significant changes within each group.

individual variability was noted—some younger patients exhibited marked epithelial staining, whereas some older patients maintained favorable meiboscores. Collectively, these results indicate that while the IPL therapy led to multi-faceted improvement across all age groups, the specific parameters showing the greatest relative change may differ with age.

These findings are consistent with the pathophysiologic differences associated with life stage. In younger patients, meibomian gland obstruction and increased meibum viscosity are thought to result from contact lens wear and residual cosmetic materials.[13–15] This observation is consistent with the baseline characteristics in our study, including lower LLT and poorer expressibility in the U group, together with their substantial post-treatment improvement in meibum function and LLT. The IPL therapy can soften inspissated meibum and reduce peri-glandular telangiectasia and inflammation,[7–12] thereby facilitating lipid outflow and enhancing the lipid layer. The resultant reinforcement of the tear film lipid layer reduces evaporation and delays tear film thinning,[26,27] providing a physiologic basis for the observed FBUT prolongation in both groups.

The observed decrease in the meiboscore, particularly for younger patients, should be interpreted with caution, given the relatively short follow-up period. This change may reflect functional improvement or enhanced visualization of the meibomian glands after treatment rather than true structural gland regeneration.

In older patients, age-related atrophy of the meibomian glands and postmenopausal hormonal changes contribute to reduced lipid secretion and increased ocular surface inflammation.[16,17] In the present study, the O group exhibited worse baseline meiboscore and corneal and conjunctival staining score. Although short-term structural recovery of atrophic glands is unlikely,[16] the anti-vascular and anti-inflammatory effects of IPL[6,9] may promote epithelial healing, accounting for the greater reduction in corneal and conjunctival staining observed in this group.

Symptom improvement was significant in the U and O groups in this study. Previous studies have demonstrated that the SPEED questionnaire provides high clinical utility and sensitivity, showing significant correlations with corneal and conjunctival staining and meibomian gland function indices.[21] Although objective findings and subjective symptoms in ocular surface disease do not always align perfectly, the parallel improvements in FBUT (in the U and O groups), meibomian gland function (particularly in the U group), corneal and conjunctival staining score (particularly in the O group), and SPEED scores (in the U and O groups) observed in this study are consistent with findings from previous randomized double-masked placebo-controlled trials,[28] prospective randomized studies,[29] and multicenter prospective investigations.[19]

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Regarding safety, no adverse events were observed in this study. Previous reports—including those involving direct eyelid application and combined meibomian gland expression—have described only transient sensations of heat or mild discomfort, with no serious adverse effects.[9,30] Systematic reviews and meta-analyses also support the rarity of severe complications,[9–11] and the procedure is generally considered safe when appropriate indications, shielding, and skin protection are followed.

This study has several limitations. It was a retrospective, single-center study, and the findings are limited to female participants; therefore, generalization to male patients should be made with caution. Concomitant in-office or at-home therapies (such as eye drops and adherence to lid hygiene) were not strictly controlled. The observation period was limited to one month after the fourth IPL session, and long-term durability of the effects remains to be verified. In particular, the persistence of changes in structural parameters such as the meiboscore and the durability of the observed age-related differences over a longer follow-up period remain unclear. Nevertheless, despite these limitations, the identification of age-related trends in relative parameter changes, the consistent multi-parameter improvements, and the absence of adverse events all strengthen the evidence supporting the efficacy and safety of the IPL therapy in women with MGD. Future studies with larger, sex-inclusive cohorts and longer follow-up periods are warranted to validate these findings and further clarify the influence of age on the therapeutic response to IPL.

Conclusions

The IPL therapy improved tear film stability and subjective symptoms in female patients with MGD across all ages. Younger patients showed greater improvement in meibomian gland function; in contrast, older patients demonstrated more pronounced reduction in corneal and conjunctival staining. Although the specific parameters with the most prominent relative changes differed by age, both the U and O groups experienced multifaceted benefits. These findings indicate that IPL is a useful and safe therapeutic option for women with MGD regardless of age.

Future studies with larger, sex-inclusive cohorts and longer follow-up periods are warranted to further elucidate age-related differences in the treatment response and determine the long-term durability of IPL therapy.

Abbreviations

MGD, meibomian gland dysfunction; IPL, intense pulsed light; FBUT, fluorescein tear film break-up time; LLT, lipid layer thickness; SPEED, Standard Patient Evaluation of Eye Dryness; TFOS DEWS II, Tear Film and Ocular Surface Society Dry Eye Workshop II.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Informed Consent

This study adhered to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Chukyo Eye Clinic (approval number: 20250328092). Because this study was retrospective, an opt-out approach approved by the ethics committee was used instead of acquisition of written informed consent.

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Author Contributions

All authors made a significant contribution to the work reported, including conception; study design; execution; acquisition, analysis, and interpretation of data; or all these areas. They also took part in drafting, revision, or critical review of the article. All authors 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

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