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Effectiveness of Intense Pulsed Light (IPL) in Meibomian Gland Dysfunction Related Dry Eye: A Systematic review

¹ Ida Ayu Bintang Maui Putri, ² Anak Agung Avrella Shora Yuananda,
³ Ni Nyoman Adi Widiastuti

^{1,2,3} Faculty of Medicine, University of Warmadewa, Indonesia

Corresponding Email : idaayu.bintang@gmail.com

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ABSTRACT

Background: Meibomian gland dysfunction (MGD) is a major contributor to evaporative dry eye disease and is characterized by obstruction of the meibomian gland ducts and altered meibum secretion. These abnormalities disrupt the tear film lipid layer, increase tear evaporation, and contribute to ocular surface inflammation and dry eye symptoms. Intense pulsed light (IPL) has emerged as a procedural treatment for MGD-related dry eye, but existing studies vary in treatment protocols, adjunctive procedures, comparators, and outcome measures.

Objective: This systematic review aimed to evaluate the effectiveness and safety of intense pulsed light in patients with meibomian gland dysfunction-related dry eye.

Methods: A systematic review was conducted in accordance with the PRISMA 2020 statement. Literature searches were performed in PubMed, Scopus, and ScienceDirect, with the final search completed on May 18, 2026. Eligible studies

included original human clinical studies evaluating IPL in patients with MGD-related dry eye. Studies assessing IPL alone, IPL combined with meibomian gland expression, IPL combined with low-level light therapy, or comparisons between IPL devices were included. The primary outcomes of interest were dry eye symptoms, tear film stability, meibomian gland function, inflammatory or mechanistic outcomes, and safety. Two reviewers independently performed study selection, data extraction, and risk of bias assessment. Because of substantial heterogeneity in study design, treatment protocol, comparator type, and outcome reporting, the findings were synthesized qualitatively.

Results: The database search identified 660 records. After duplicate removal, title and abstract screening, and full-text assessment, 13 studies were included in the final qualitative synthesis. The included studies consisted of randomized controlled trials, randomized paired-eye studies, prospective comparative studies, prospective interventional studies, and mechanistic clinical studies. Overall, IPL was associated with improvement in tear film stability and meibomian gland-related outcomes, including tear breakup time, non-invasive tear breakup time, lipid layer thickness, meibum quality, gland expressibility, and lid margin abnormalities. Patient-reported symptoms also improved in many studies, although symptom outcomes were less consistent across controlled trials than objective tear film and gland-related parameters. Mechanistic studies reported reductions in inflammatory

mediators, including IL-17A, IL-6, PGE2, IL-1 β , IL-17F, and MMP-9, suggesting a possible anti-inflammatory effect of IPL. Safety findings were generally favorable, with no consistent reports of serious adverse events. Reported adverse effects were mostly mild and transient, including pain, burning sensation, and isolated partial eyelash loss.

Conclusion: Current evidence suggests that IPL is an effective and generally well-tolerated treatment for MGD-related dry eye, particularly for improving tear film stability and meibomian gland function. Symptom improvement is commonly reported but less consistent than objective clinical improvement. Because several studies evaluated IPL in combination with meibomian gland expression or low-level light therapy, the independent effect of IPL should be interpreted cautiously. Further high-quality randomized controlled trials with standardized IPL protocols, longer follow-up, consistent outcome measures, and systematic safety reporting are needed.

Keywords: Intense pulsed light; meibomian gland dysfunction; dry eye disease; evaporative dry eye; tear film stability; systematic review.

INTRODUCTION

Dry eye disease is a multifactorial ocular surface disorder characterized by tear film instability, ocular discomfort, visual disturbance, and ocular surface inflammation. Among its etiological subtypes, evaporative dry eye is commonly associated with meibomian gland dysfunction (MGD), a chronic abnormality of the meibomian glands characterized by terminal duct obstruction and qualitative or quantitative changes in meibum secretion. Impaired meibomian gland function disrupts the lipid layer of the tear film, increases tear evaporation, and contributes to tear film instability, ocular surface inflammation, and dry eye symptoms. Because of this pathophysiological relationship, MGD is regarded as a major contributor to dry eye disease, particularly the evaporative subtype.^{1,2}

The clinical burden of MGD-related dry eye is substantial because the condition may cause chronic ocular irritation, foreign body sensation, burning, fluctuating vision, and reduced quality of life. The disease process is often self-perpetuating: altered meibum quality and gland obstruction promote tear film instability, while ocular surface inflammation further worsens glandular dysfunction and dry eye symptoms. Conventional treatment approaches include eyelid hygiene, warm compresses, artificial tears, anti-inflammatory therapy, antibiotics, omega-3 supplementation, and meibomian gland expression. Although these therapies can provide symptomatic relief, many patients experience incomplete or temporary improvement, especially in chronic, moderate-to-severe, or refractory MGD.^{3,4}

Intense pulsed light (IPL) has emerged as a procedural therapy for MGD-related dry eye. Initially used in dermatology for conditions such as rosacea, telangiectasia, and vascular skin lesions, IPL later gained attention after ocular surface improvement was observed in patients receiving IPL for facial rosacea. In ophthalmic use, IPL is delivered to the periocular or eyelid region using controlled pulses of non-coherent polychromatic light. Its proposed mechanisms include heating and softening of abnormal meibum, improvement of meibomian gland secretion, closure of abnormal

telangiectatic vessels, reduction of inflammatory mediators, modulation of eyelid margin microbiology, and possible effects on local tissue metabolism. These mechanisms are relevant to MGD-related dry eye because the condition involves gland obstruction, altered lipid secretion, eyelid margin inflammation, and tear film instability.^{5,6}

Clinical studies have evaluated IPL using different protocols and treatment settings. Some studies assessed IPL as a standalone intervention, while others evaluated IPL combined with meibomian gland expression or low-level light therapy. Comparators have included placebo or sham treatment, meibomian gland expression alone, conventional hot compress and gland massage, LipiFlow, low-level light therapy alone, and different IPL devices. Across these studies, commonly assessed outcomes include dry eye symptom scores, tear breakup time, non-invasive tear breakup time, lipid layer thickness, tear meniscus height, ocular surface staining, meibomian gland expressibility, meibum quality, lid margin abnormalities, inflammatory markers, and adverse events.⁷⁻⁹

Despite the growing number of clinical studies, the overall evidence remains heterogeneous. Differences in IPL devices, fluence settings, number of sessions, treatment intervals, anatomical treatment area, adjunctive procedures, comparator groups, and follow-up duration make it difficult to draw a single uniform conclusion about the effectiveness of IPL. Moreover, because many studies combine IPL with meibomian gland expression or low-level light therapy, the independent contribution of IPL is not always easy to isolate. This heterogeneity highlights the need for a systematic synthesis focused specifically on the role of IPL in MGD-related dry eye.

Therefore, this systematic review aimed to evaluate the effectiveness of intense pulsed light in patients with meibomian gland dysfunction-related dry eye. The review focused on the effects of IPL on dry eye symptoms, tear film stability, meibomian gland function, inflammatory and mechanistic outcomes, and safety, based exclusively on the included clinical studies.

METHODS

Study Design and Reporting Standards

This study was conducted as a systematic review to evaluate the effectiveness and safety of intense pulsed light-based therapy in patients with meibomian gland dysfunction-related dry eye. The review was designed to identify, appraise, and synthesize clinical evidence on the effects of intense pulsed light therapy on dry eye symptoms, tear film stability, meibomian gland function, inflammatory or mechanistic outcomes, and treatment-related adverse events.

The conduct and reporting of this systematic review were guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. The review process included the formulation of predefined eligibility criteria, systematic literature searching across selected electronic databases, structured study selection, data extraction, risk of bias assessment, and qualitative evidence synthesis. Two independent reviewers were involved in the study selection, data extraction, and methodological appraisal processes. Any disagreements between reviewers were resolved through discussion and consensus.

Given the clinical and methodological heterogeneity among the included studies, particularly in terms of treatment protocols, comparator groups, outcome measures, follow-up duration, and whether IPL was administered alone or in combination with other procedures, the findings were synthesized narratively rather than quantitatively.

Eligibility Criteria

Studies were considered eligible if they evaluated intense pulsed light-based therapy in patients with dry eye disease related to meibomian gland dysfunction. The population of interest included adult patients diagnosed with meibomian gland dysfunction, evaporative dry eye, or dry eye disease attributable to meibomian gland dysfunction, based on clinical symptoms, eyelid margin abnormalities, meibomian

gland obstruction, impaired meibum quality or expressibility, tear film instability, or other diagnostic criteria reported by the original studies.

Eligible interventions included intense pulsed light therapy administered either as a standalone treatment or as part of an IPL-based therapeutic approach. Studies evaluating IPL combined with meibomian gland expression, low-level light therapy, or other procedural adjuncts were included when IPL represented a central component of the intervention. Studies comparing different IPL devices or IPL protocols were also considered eligible.

Eligible comparators included sham or placebo treatment, meibomian gland expression alone, conventional therapy such as warm compress or eyelid massage, other device-based treatments, alternative light-based therapy, or baseline status in single-arm interventional studies. No restriction was applied based on comparator type, treatment frequency, treatment interval, IPL device, or follow-up duration.

The outcomes of interest included clinical symptoms, tear film parameters, meibomian gland function, ocular surface findings, inflammatory or mechanistic biomarkers, and safety outcomes. Symptom-related outcomes included measures such as the Ocular Surface Disease Index, Standard Patient Evaluation of Eye Dryness, Symptom Assessment in Dry Eye, Eye Dryness Score, or other patient-reported symptom assessments. Objective outcomes included tear breakup time, non-invasive tear breakup time, lipid layer thickness, tear meniscus height, Schirmer test, corneal or conjunctival staining, meibomian gland expressibility, meibum quality, meibomian gland dropout, lid margin abnormalities, and inflammatory markers in tears or ocular surface samples. Safety outcomes included adverse events, serious adverse events, ocular or periocular complications, treatment tolerability, and procedure-related discomfort.

Original human clinical studies were eligible for inclusion, including randomized controlled trials, non-randomized controlled trials, prospective interventional studies, paired-eye studies, and secondary clinical or mechanistic reports derived from eligible clinical cohorts. Review articles, editorials, letters without

original data, conference abstracts without sufficient clinical data, animal studies, in vitro studies, and studies not evaluating outcomes relevant to the objectives of this review were excluded. Only full-text articles available in English were included.

Information Sources

The literature search was conducted using three electronic databases: PubMed, Scopus, and ScienceDirect. These databases were selected to provide broad coverage of biomedical, ophthalmologic, and clinical research relevant to intense pulsed light therapy, meibomian gland dysfunction, and dry eye disease.

The final literature search was completed on May 18, 2026. All records retrieved from the database searches were collected for screening, and duplicate records were removed before title and abstract screening. Only studies identified through these predefined database searches and meeting the eligibility criteria were considered for inclusion in the review.

Search Strategy

The search strategy was developed to identify clinical studies evaluating intense pulsed light therapy in patients with meibomian gland dysfunction-related dry eye. The search terms were structured around three main concepts: intense pulsed light therapy, meibomian gland dysfunction, and dry eye disease.

For PubMed, the search strategy combined Medical Subject Headings and free-text terms related to intense pulsed light therapy, meibomian gland dysfunction, and dry eye syndromes. For Scopus and ScienceDirect, equivalent keyword-based search strategies were adapted according to the search format and indexing system of each database. Boolean operators were used to combine synonyms within each concept and to link the three main search concepts.

The search was limited to studies relevant to human clinical evidence on intense pulsed light-based therapy for meibomian gland dysfunction-related dry eye. The retrieved records from PubMed, Scopus, and ScienceDirect were subsequently combined, and duplicate records were removed before the screening process. Detailed

search results from each database and the study selection process are presented in the Results section.

Study Selection

All records identified through the electronic database searches were imported and compiled for study selection. Duplicate records were removed before the screening process. Two reviewers independently screened the titles and abstracts of the remaining records according to the predefined eligibility criteria. Articles that were clearly irrelevant to the review question, did not evaluate intense pulsed light-based therapy, did not involve meibomian gland dysfunction-related dry eye, or did not report relevant clinical outcomes were excluded at this stage.

The full texts of potentially eligible articles were then retrieved and assessed independently by the same two reviewers. Each full-text article was evaluated for population, intervention, comparator when applicable, outcome relevance, study design, and availability of sufficient clinical data. Studies were included in the final review when they met all predefined eligibility criteria. Articles were excluded at the full-text stage if their outcomes were not aligned with the objectives of this systematic review.

Any disagreements between the two reviewers during title and abstract screening or full-text assessment were resolved through discussion and consensus. The complete study selection process, including the number of records identified, screened, excluded, and included, is reported in the Results section and summarized in the PRISMA flow diagram.

Data Extraction

Data extraction was performed using a standardized data extraction form developed for this review. Two reviewers independently extracted relevant information from each included study, and any discrepancies were resolved through discussion and consensus.

The extracted data included the first author, year of publication, country or study setting, study design, sample size, participant characteristics, diagnostic criteria

or clinical definition of meibomian gland dysfunction-related dry eye, intervention details, comparator or control condition, follow-up duration, outcome measures, main clinical findings, and reported safety outcomes.

Intervention-related data included the type of IPL device or treatment platform when reported, treatment protocol, number of treatment sessions, treatment interval, treatment area, IPL fluence or energy parameters, and whether IPL was administered alone or in combination with adjunctive procedures such as meibomian gland expression or low-level light therapy. Comparator data were extracted when available, including sham treatment, meibomian gland expression alone, conventional therapy, alternative device-based therapy, or baseline comparison in single-arm studies.

Outcome data were extracted according to the main domains of this review: dry eye symptoms, tear film stability, meibomian gland function, ocular surface findings, inflammatory or mechanistic outcomes, and safety. Symptom outcomes included OSDI, SPEED, SANDE, Eye Dryness Score, or other patient-reported measures. Objective clinical outcomes included TBUT, NIBUT, lipid layer thickness, tear meniscus height, Schirmer test, corneal or conjunctival staining, meibomian gland expressibility, meibum quality, meibomian gland dropout, and lid margin abnormalities. Mechanistic outcomes included tear cytokines, inflammatory mediators, ocular surface immune markers, vascular or metabolic findings, and other biological parameters reported by the included studies.

For studies derived from overlapping or related clinical cohorts, the extracted data were interpreted according to the specific outcome focus of each article, such as clinical efficacy, biomarker changes, or mechanistic findings. Safety data were extracted separately and included adverse events, serious adverse events, ocular or periocular complications, pain or discomfort during treatment, and treatment discontinuation when reported.

Risk of Bias Assessment

The methodological quality of the included studies was assessed independently by two reviewers using validated risk of bias tools according to study design.

Randomized controlled trials and randomized paired-eye trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool. Non-randomized studies, prospective single-arm interventional studies, retrospective studies, and uncontrolled clinical studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool.

For randomized studies, the RoB 2 assessment considered bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of the reported result. Particular attention was given to whether allocation concealment, participant masking, assessor masking, and handling of missing data were adequately reported.

For non-randomized studies, ROBINS-I was applied to assess bias due to confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. Studies without a control group were interpreted cautiously because of the increased possibility of confounding, placebo effects, regression to the mean, and outcome measurement bias.

Each study was assigned an overall risk of bias judgment according to the criteria of the respective tool. Any disagreements between the two reviewers were resolved through discussion and consensus with the help of a third reviewer. The results of the risk of bias assessment were incorporated into the qualitative interpretation of the evidence, with greater emphasis placed on findings from controlled and lower-risk studies.

Data Synthesis

The findings of the included studies were synthesized using a qualitative narrative approach. A quantitative meta-analysis was not performed because the included studies showed substantial clinical and methodological heterogeneity, particularly in study design, treatment protocol, adjunctive procedures, comparator type, follow-up duration, and outcome reporting.

The synthesis was structured according to the main outcome domains of the review. Findings were organized to describe the effects of IPL-based therapy on dry eye symptoms, tear film stability, meibomian gland function, inflammatory or mechanistic outcomes, and safety. Within each domain, results were compared narratively by considering the direction of effect, consistency of findings across studies, and strength of the supporting study design.

Studies were also interpreted according to the type of IPL-based intervention, including IPL alone, IPL combined with meibomian gland expression, IPL combined with low-level light therapy, and comparisons between different IPL protocols or devices. Greater interpretive weight was given to randomized, controlled, and masked studies, whereas uncontrolled or open-label studies were interpreted cautiously because of their greater susceptibility to bias.

Safety findings were synthesized descriptively by summarizing the reported adverse events, procedure-related discomfort, ocular or periocular complications, treatment discontinuation, and serious adverse events when available. Overall conclusions were developed by integrating the consistency of clinical findings with the methodological quality and risk of bias of the included studies.

RESULTS

Study Selection

The study selection process is summarized in the PRISMA flow diagram. The database search identified a total of 660 records, including 182 records from PubMed, 263 records from Scopus, and 215 records from ScienceDirect. After the removal of 144 duplicate records, 516 records remained for title and abstract screening.

During title and abstract screening, 499 records were excluded because they did not meet the predefined eligibility criteria or were not relevant to the objective of this review. Seventeen full-text articles were subsequently assessed for eligibility. Of these, four articles were excluded because their reported outcomes were not aligned with the

objectives of this systematic review. Ultimately, 13 articles met the eligibility criteria and were included in the final qualitative synthesis.

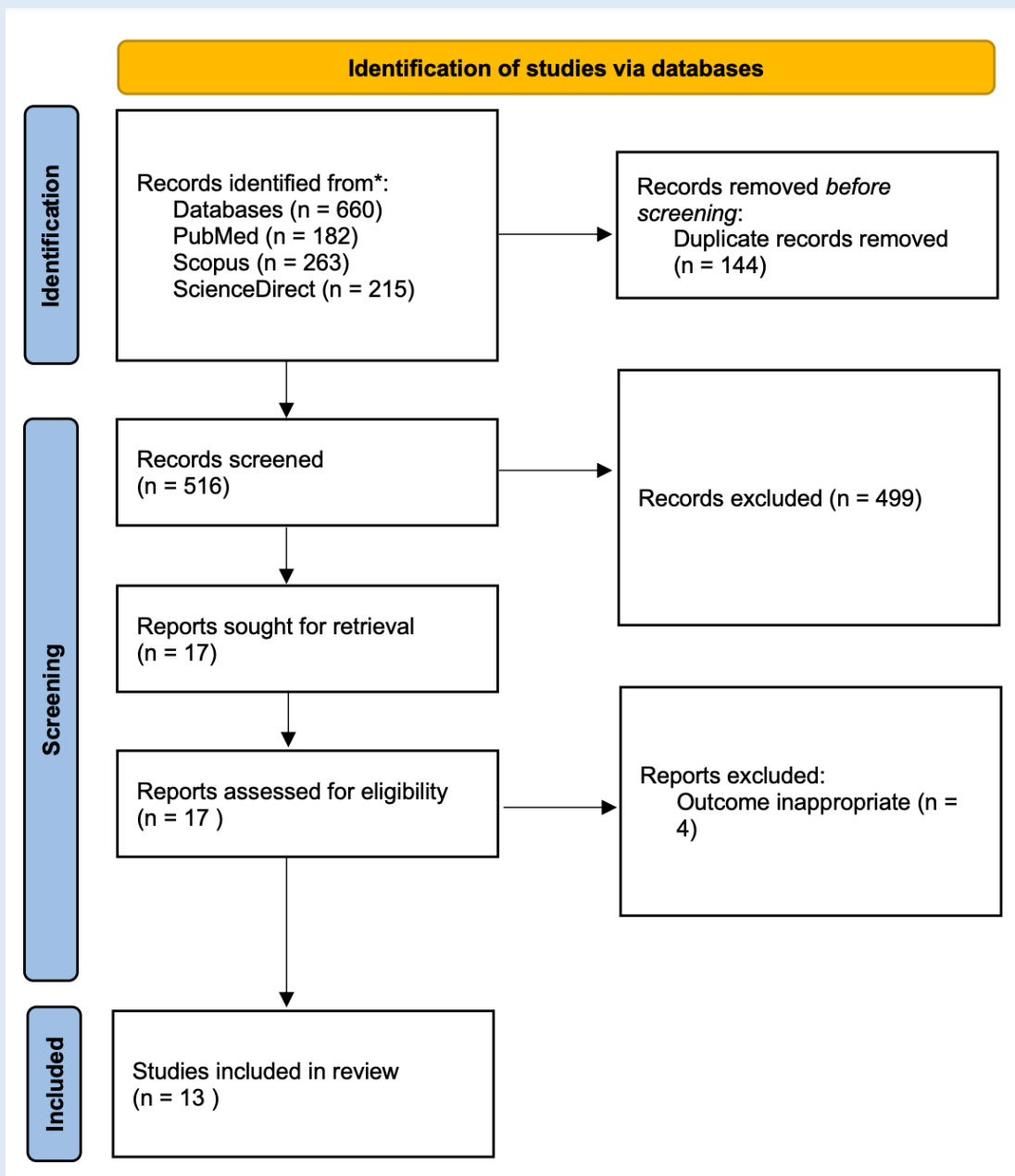


Figure 1. PRISMA Flow Chart

Study Characteristics

The main characteristics of the 13 included studies are summarized in Table 1. The included studies evaluated intense pulsed light-based therapy in patients with meibomian gland dysfunction-related dry eye. The body of evidence consisted of randomized controlled trials, randomized paired-eye studies, prospective comparative studies, prospective single-arm interventional studies, and mechanistic clinical studies.

The included studies varied in sample size, treatment protocol, number of IPL sessions, comparator type, adjunctive procedures, and follow-up duration. IPL was evaluated either as a standalone intervention or in combination with meibomian gland expression or low-level light therapy. Comparator conditions included sham or placebo treatment, meibomian gland expression alone, conventional hot compress and gland massage, low-level light therapy alone, LipiFlow, and alternative IPL devices. Several uncontrolled studies compared post-treatment outcomes with baseline values.

Across the included studies, the most frequently reported outcomes were dry eye symptom scores, tear breakup time, non-invasive tear breakup time, lipid layer thickness, tear meniscus height, ocular surface staining, meibomian gland expressibility, meibum quality, lid margin abnormalities, inflammatory markers, and adverse events.

Table 1. Characteristics of Included Studies

Study	Study Design	Participants	Interventions	Comparator	Follow-up	Main Findings
D'Souza et al. (2021)	Prospective interventional longitudinal study	47 subjects / 94 eyes with chronic MGD and evaporative dry eye	Single session of combined IPL and low-level light therapy using the Eye-light device	Baseline comparison	3 and 6 months after treatment	OSDI, TBUT, and meibomian gland expressibility improved after treatment and were sustained during follow-up. Tear inflammatory markers, including IL-1 β , IL-17F, MMP-9, and the MMP-9/TIMP-1 ratio, decreased after treatment.
Vergés et al. (2021)	Prospective longitudinal open-label study	44 patients / 88 eyes with moderate to severe MGD-related dry eye	Four IPL sessions using Thermaeye Plus on days 1, 14, 28, and 49	Baseline comparison	1 and 4 months after the final IPL session	Dry eye symptoms and OSDI scores improved after treatment. Clinical signs, including telangiectasia and blepharitis, also improved. No local, periocular, or systemic complications were reported.
Peng et al. (2022)	Prospective interventional study	37 patients / 74 eyes with MGD and evaporative dry eye	Three IPL sessions combined with meibomian gland expression at 28-day intervals	Baseline comparison	28 days after the first and third IPL sessions	OSDI, SPEED, lipid layer thickness, tear meniscus height, meibomian gland loss, meibomian gland expression scores, and pain scores improved after treatment.
Chiang et al. (2025)	Double-masked randomized paired-eye clinical trial	24 participants with MGD and dry eye disease	Combined IPL and low-level light therapy in one eye	Low-level light therapy alone in the fellow eye	2 weeks and 3 months after the final treatment	Symptom frequency improved with both treatments, while symptom severity

						improved only with combined IPL and low-level light therapy. Meibum expressibility improved with both modalities during follow-up.
D'Souza et al. (2023)	Prospective randomized double-blinded controlled study	100 patients / 200 eyes with MGD and evaporative dry eye	Three sessions of IPL combined with low-level light therapy at 15-day intervals	Sham treatment	1 and 2 months after completing treatment	The treatment group showed significant improvement in OSDI and TBUT compared with the control group. Schirmer test did not show significant change, and meibomian gland expression improved but was not statistically significant.
Han et al. (2025)	Prospective randomized controlled comparative study	95 patients with severe MGD	IPL combined with meibomian gland expression	Manual meibomian gland expression alone or LipiFlow	1, 3, and 6 months after treatment	All treatment groups showed improvement in signs and symptoms. IPL combined with meibomian gland expression showed the most consistent and sustained improvement in OSDI and NIBUT during follow-up.
Yan and Wu (2021)	Randomized clinical trial	132 patients with MGD-related dry eye	IPL therapy	Meibomian gland massage combined with hot compress	7 and 30 days after treatment	The total effective rate was higher in the IPL group than in the control group. Meibomian gland quality score, lacrimal river height, and tear secretion-related measures

						improved over time. Adverse event rates did not differ significantly between groups.
Jiang et al. (2022)	Multicenter randomized patient-blinded parallel-control non-inferiority trial	132 patients with MGD-related dry eye	New-generation IPL device, Eysis	Traditional IPL device, E-Eye	Day 7 and day 14	The new-generation IPL device was non-inferior to the traditional IPL device. OSDI, TBUT, Schirmer test, tear meniscus height, corneal fluorescein staining, and meibomian gland signs improved after treatment.
Rong et al. (2018)	Prospective randomized double-masked paired-eye controlled study	44 patients with MGD	IPL applied directly on the eyelids combined with meibomian gland expression	Sham IPL combined with meibomian gland expression in the fellow eye	12 weeks	IPL-treated eyes showed greater improvement in meibomian gland yielding secretion score and TBUT than control eyes. SPEED and CFS scores improved in both treated and control eyes. Mild pain or burning occurred in five patients, and partial eyelash loss occurred in one patient.
Liu et al. (2017)	Randomized double-masked controlled mechanistic clinical study	44 patients / 88 eyes with MGD-related dry eye	IPL combined with meibomian gland expression	Sham IPL combined with meibomian gland expression	4 and 12 weeks	IL-17A and IL-6 decreased significantly after IPL compared with sham at measured time points. PGE2 also decreased significantly compared with sham at week 12. Some

						inflammatory marker changes correlated with ocular surface parameters.
Toyos et al. (2022)	Prospective multicenter randomized double-masked active-controlled trial	88 randomized subjects; 82 completed efficacy analysis	Four sessions of IPL followed by meibomian gland expression at 2-week intervals	Sham IPL followed by meibomian gland expression	4 weeks after the fourth treatment session	TBUT improved more in the IPL group than in the control group. Meibomian gland score, eye dryness score, expressible gland number, meibum quality, and pain due to meibomian gland expression also showed greater improvement in the IPL group. OSDI improved in both groups without a significant between-group difference.
Arita et al. (2019)	Prospective randomized controlled study	45 patients / 90 eyes with refractory MGD	Eight sessions of IPL combined with meibomian gland expression at 3-week intervals	Meibomian gland expression alone	Up to 32 weeks after treatment onset	IPL combined with meibomian gland expression produced greater improvements in lipid layer grade, lipid layer thickness, NIBUT, fluorescein BUT, lid margin abnormalities, meibum grade, SPEED score, and CFS score than meibomian gland expression alone.
Xue et al. (2020)	Prospective double-masked randomized placebo-controlled trial	87 symptomatic participants with clinical signs of MGD	IPL therapy with four or five homogeneously sequenced light pulses	Placebo treatment	Day 105	IPL improved dry eye symptom scores, tear film lipid layer thickness, and meibomian gland

						capping. Five-flash treatment showed earlier clinical improvement than four-flash treatment in several outcomes. No adverse events were reported.
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Intervention Characteristics

The intervention characteristics of the included studies varied in terms of IPL device, treatment schedule, anatomical treatment area, adjunctive procedures, comparator, and follow-up duration. The included studies evaluated IPL as a standalone intervention, IPL combined with meibomian gland expression, IPL combined with low-level light therapy, and comparisons between different IPL devices or treatment modalities.

IPL combined with meibomian gland expression was evaluated in several studies. Rong et al. administered IPL directly to the eyelids using the M22 IPL system, with ocular protection provided by a Jaeger lid plate. The study eye received three IPL sessions at 4-week intervals, while the fellow eye received sham IPL; both eyes underwent meibomian gland expression and used artificial tears during the study period.⁷ Liu et al. used the same M22 IPL platform in a randomized paired-eye design, in which study eyes received IPL followed by meibomian gland expression and control eyes received sham IPL followed by the same expression procedure. Treatments were administered three times at approximately 4-week intervals.⁵ Toyos et al. evaluated four treatment sessions of IPL followed by meibomian gland expression at 2-week intervals, using sham IPL followed by meibomian gland expression as the control condition.² Arita et al. administered eight sessions of IPL combined with meibomian gland expression at 3-week intervals and compared this regimen with meibomian gland expression alone.¹ Peng et al. evaluated three sessions of IPL combined with meibomian gland expression, with treatments performed at 28-day intervals.¹⁰ Han et al. compared IPL combined with meibomian gland expression with manual meibomian gland expression alone and LipiFlow in patients with severe MGD.¹¹

IPL combined with low-level light therapy was evaluated in three studies. D'Souza et al. assessed a single session of combined IPL and low-level light therapy using the Eye-light device in patients with chronic MGD and evaporative dry eye.¹² In a randomized controlled study, D'Souza et al. administered three sessions of IPL combined with low-level light therapy at 15-day intervals and compared the

intervention with sham treatment.⁴ Chiang et al. used a randomized paired-eye design in which one eye received combined IPL and low-level light therapy, while the fellow eye received low-level light therapy alone. Four treatment sessions were performed 2 to 3 weeks apart.⁹

IPL as a standalone intervention was assessed in selected studies. Vergés et al. administered four sessions of Thermaeye Plus IPL on days 1, 14, 28, and 49, without post-treatment mechanical meibomian gland expression.³ Xue et al. evaluated IPL therapy using four-flash and five-flash treatment protocols with the E-Eye Intense Regulated Pulsed Light device and compared these with placebo treatment. Mechanical meibum expression was not performed during the study period.⁶ Yan and Wu compared IPL therapy with meibomian gland massage combined with hot compress.¹³ Jiang et al. compared a new-generation IPL device, Eysis, with a traditional IPL device, E-Eye, in a multicenter randomized non-inferiority trial.⁸

The anatomical treatment area differed across the included studies. Most studies applied IPL to the inferior periocular region, lower eyelid region, cheek area, or area below the lower eyelids. In contrast, Rong et al. and Liu et al. applied IPL directly to the eyelids under ocular shielding.^{5,7} The number of IPL sessions ranged from one session to eight sessions, and treatment intervals ranged from 1 week to 4 weeks. Follow-up duration ranged from 14 days to 6 months, with some studies reporting outcomes according to time from treatment onset rather than time after final treatment.

Effects on Dry Eye Symptoms

Dry eye symptoms were assessed using several patient-reported outcome measures, including OSDI, SPEED, SANDE, Eye Dryness Score, and symptom severity or frequency scales. Most included studies reported improvement in subjective symptoms after IPL-based therapy.

D'Souza et al. reported a significant reduction in OSDI after combined IPL and low-level light therapy, with improvement observed at 3 months and maintained at 6 months after treatment.¹² In the randomized controlled study by D'Souza et al., the group receiving IPL combined with low-level light therapy showed significantly

greater improvement in OSDI compared with the sham-treated control group.⁴ Vergés et al. also reported a significant decrease in OSDI and symptom scores after four sessions of Thermaeye Plus IPL, with improvement maintained until the final follow-up.³

In studies evaluating IPL combined with meibomian gland expression, symptom improvement was also frequently reported. Peng et al. found significant reductions in both OSDI and SPEED scores after three sessions of IPL combined with meibomian gland expression.¹⁰ Rong et al. reported that SPEED scores improved in both IPL-treated eyes and control eyes, although between-eye differences in SPEED score changes were not significant.⁷ Toyos et al. found improvement in Eye Dryness Score that was greater in the IPL plus meibomian gland expression group than in the sham plus meibomian gland expression group; however, OSDI improved in both groups without a significant between-group difference.² Arita et al. reported significant improvement in SPEED score after IPL combined with meibomian gland expression, with a significant difference compared with meibomian gland expression alone at 32 weeks after treatment onset.¹

In comparative and device-based studies, symptom scores also improved after IPL-based treatment. Han et al. reported that all treatment groups showed improvement in OSDI, with IPL combined with meibomian gland expression showing consistent improvement during follow-up.¹¹ Jiang et al. reported significant improvement in OSDI after treatment with both new-generation and traditional IPL devices.⁸ Xue et al. reported significant decreases in OSDI, SPEED, and SANDE scores after IPL therapy, particularly after repeated treatment sessions.⁶ Chiang et al. reported that symptom frequency improved after both combined IPL and low-level light therapy and low-level light therapy alone, while symptom severity improved only after combined therapy.⁹

Effects on Tear Film Stability and Tear Film Parameters

Tear film stability was most commonly assessed using fluorescein tear breakup time or non-invasive tear breakup time. Several studies reported improvement in TBUT or NIBUT after IPL-based treatment.

D'Souza et al. reported a significant increase in TBUT after combined IPL and low-level light therapy, with the effect maintained during the 6-month follow-up.¹² In the randomized controlled study by D'Souza et al., TBUT improved significantly in the IPL plus low-level light therapy group compared with the control group.⁴ Vergés et al. reported improvement in non-invasive tear breakup measures after Thermaeye Plus IPL.³

Among studies evaluating IPL combined with meibomian gland expression, Rong et al. found that TBUT improved in IPL-treated eyes and that the change in TBUT was greater than in control eyes receiving sham IPL with meibomian gland expression.⁷ Toyos et al. reported that TBUT increased from baseline in both treatment arms, with a significantly greater increase in the IPL plus meibomian gland expression group than in the sham plus meibomian gland expression group.² Arita et al. reported significant improvements in both non-invasive breakup time and fluorescein breakup time in the IPL plus meibomian gland expression group compared with meibomian gland expression alone.¹ Han et al. reported improvement in NIBUT across treatment groups, with sustained improvement observed in the IPL plus meibomian gland expression group during follow-up.¹¹

Other tear film parameters were also reported. Peng et al. found significant improvement in lipid layer thickness and tear meniscus height after IPL combined with meibomian gland expression.¹⁰ Arita et al. reported significant improvement in lipid layer thickness and lipid layer grade after IPL combined with meibomian gland expression.¹ Xue et al. reported increased tear film lipid layer thickness after IPL therapy compared with baseline.⁶ Jiang et al. reported improvement in tear meniscus height, TBUT, and Schirmer test after IPL treatment in both device groups.⁸ In contrast, D'Souza et al. reported no significant change in Schirmer test after IPL combined with low-level light therapy in the randomized controlled study.⁴

Effects on Meibomian Gland Function

Meibomian gland function was assessed using measures such as meibomian gland expressibility, meibum quality, meibomian gland yielding secretion score,

meibomian gland score, meibomian gland expression score, lid margin abnormalities, plugging, capping, and meibography.

D'Souza et al. reported significant improvement in meibomian gland expressibility after combined IPL and low-level light therapy.¹² In the randomized controlled study by D'Souza et al., meibomian gland expression improved in the treatment group, although the reported improvement was not statistically significant compared with control.⁴ Vergés et al. reported improvement in clinical signs related to MGD, including eyelid margin findings such as telangiectasia and blepharitis.³

In IPL plus meibomian gland expression studies, Rong et al. reported greater improvement in meibomian gland yielding secretion score in IPL-treated eyes than in sham-treated control eyes.⁷ Toyos et al. reported greater improvement in meibomian gland score, number of expressible glands, and predominant meibum quality in the IPL plus meibomian gland expression group compared with the control group.² Arita et al. reported significant improvement in meibum grade and lid margin abnormalities after IPL combined with meibomian gland expression compared with meibomian gland expression alone.¹ Peng et al. reported improvement in meibomian gland expression scores and meibomian gland loss after three sessions of IPL combined with meibomian gland expression.¹⁰ Han et al. reported improvement in meibomian gland expressibility across treatment groups, while meibography scores showed minimal change during follow-up.¹¹

In IPL-only or device-comparison studies, Xue et al. reported decreased meibomian gland capping after IPL therapy.⁶ Jiang et al. reported improvement in meibomian gland signs and meibum quality after treatment with both new-generation and traditional IPL devices.⁸ Yan and Wu reported improvement in meibomian gland quality score after IPL therapy compared with conventional massage and hot compress treatment.¹³

Inflammatory and Mechanistic Outcomes

Several studies reported inflammatory or mechanistic outcomes related to IPL-based therapy. D'Souza et al. evaluated tear fluid and ocular surface immune markers

after combined IPL and low-level light therapy. The study reported reductions in tear levels of IL-1 β , IL-17F, MMP-9, and the MMP-9/TIMP-1 ratio, as well as changes in ocular surface immune cell proportions after treatment.¹²

Liu et al. specifically evaluated tear inflammatory markers after IPL combined with meibomian gland expression. IL-17A and IL-6 decreased significantly after IPL treatment compared with sham treatment at measured time points, and PGE2 decreased significantly compared with sham at week 12. The study also reported correlations between selected cytokine levels and ocular surface parameters before and after IPL treatment.⁵

Chiang et al. assessed mechanistic parameters using laser Doppler flowmetry, tissue oximetry, and fluorescence measures related to lower eyelid tissue metabolism. The study reported changes in tissue flavin fluorescence after combined IPL and low-level light therapy, while clinical and mechanistic outcomes were compared with low-level light therapy alone in the fellow eye.⁹

Xue et al. evaluated ocular surface microbiological and cytology-related markers. The study reported changes in dry eye symptomatology and lipid layer measures, accompanied by inhibited *Corynebacterium macginleyi* growth after IPL therapy. Inflammatory and goblet cell function marker expression was also assessed at baseline and final follow-up.⁶

Safety and Adverse Events

Safety outcomes were reported in most included studies. Overall, the studies described IPL-based therapy as well tolerated, with few serious safety concerns reported.

D'Souza et al. monitored treatment-related side effects after combined IPL and low-level light therapy and did not emphasize serious adverse events during follow-up.¹² In the randomized controlled study by D'Souza et al., the treatment was reported as effective compared with sham, without highlighted treatment-related adverse effects.⁴ Vergés et al. reported no local ocular, periocular, or systemic complications

after Thermoeye Plus IPL.³ Xue et al. reported no adverse events during the study period.⁶

In studies involving IPL combined with meibomian gland expression, Rong et al. reported mild pain and burning during IPL treatment in five patients and partial eyelash loss in one patient.⁷ Toyos et al. reported no serious adverse events and noted a slight tendency for more adverse events in the control group than in the IPL group.² Arita et al. reported no changes in visual acuity, intraocular pressure, lens opacity, or fundus condition after IPL combined with meibomian gland expression.¹ Yan and Wu reported no significant difference in adverse event incidence between the IPL group and the control group.¹³ Jiang et al. reported no significant difference in adverse event incidence between the new-generation and traditional IPL device groups.⁸

Risk of Bias Assessment

The risk of bias assessment is summarized in Table 2 and Table 3. Randomized controlled trials and randomized paired-eye trials were assessed using the RoB 2 tool, while non-randomized and single-arm prospective studies were assessed using ROBINS-I. Overall, the risk of bias varied across the included studies, mainly because of differences in randomization methods, masking procedures, comparator design, missing data, and the use of subjective outcome measures.

Among the randomized studies, Xue et al. was judged to have low overall risk of bias because it used a prospective, double-masked, randomized, placebo-controlled design with masked outcome assessment and a placebo comparator. The remaining randomized studies were judged as having some concerns. Liu et al. used a randomized, double-masked, paired-eye controlled design and primarily assessed objective inflammatory outcomes, but was judged as having some concerns because of potential concerns in the selection of the reported result. Rong et al., Toyos et al., Jiang et al., Chiang et al., Arita et al., D'Souza et al., Han et al., and Yan and Wu were also judged as having some concerns, mainly because of issues related to paired-eye design, protocol complexity, active-comparator design, incomplete masking, sample size, missing outcome data, or outcome measurement considerations.^{1,2,5-7}

Among the non-randomized studies, D'Souza et al., Vergés et al., and Peng et al. were judged to have serious overall risk of bias. These studies used prospective interventional designs without randomized control groups, making them more susceptible to confounding, regression to the mean, placebo effects, and outcome measurement bias. Nevertheless, these studies provided descriptive clinical data on IPL-based therapy and were retained in the qualitative synthesis.^{3,10,12}

Table 2. RoB 2 Assessment of Randomized Controlled and Randomized Paired-Eye Studies

Study	Bias arising from the randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Liu et al. (2017)	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Rong et al. (2018)	Low risk	Some concerns	Low risk	Some concerns	Some concerns	Some concerns
Arita et al. (2019)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Xue et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Yan and Wu (2021)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Jiang et al. (2022)	Low risk	Some concerns	Low risk	Some concerns	Some concerns	Some concerns
Toyos et al. (2022)	Low risk	Some concerns	Some concerns	Low risk	Some concerns	Some concerns
D'Souza et al. (2023)	Some concerns	Some concerns	Low risk	Some concerns	Some concerns	Some concerns
Chiang et al. (2025)	Low risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
Han et al. (2025)	Low risk	Some concerns	Low risk	Some concerns	Some concerns	Some concerns

Table 3. ROBINS-I Assessment of Non-randomized Included Studies

Study	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall risk of bias
D'Souza et al. (2021)	Serious	Moderate	Low	Moderate	Moderate	Serious	Moderate	Serious
Vergés et al. (2021)	Serious	Moderate	Low	Moderate	Moderate	Serious	Moderate	Serious
Peng et al. (2022)	Serious	Moderate	Low	Moderate	Moderate	Serious	Moderate	Serious

DISCUSSION

Summary of Main Findings

This systematic review synthesized evidence from 13 clinical studies evaluating the effectiveness of intense pulsed light (IPL) in patients with meibomian gland dysfunction-related dry eye. Across the included studies, IPL was associated with improvement in several clinically relevant outcomes, particularly tear film stability, meibomian gland function, and patient-reported dry eye symptoms. However, the magnitude and consistency of these findings varied across studies, partly because IPL was delivered using different protocols and was sometimes combined with adjunctive procedures such as meibomian gland expression or low-level light therapy.

The most consistent improvements were observed in objective outcomes related to evaporative dry eye, including tear breakup time, non-invasive tear breakup time, lipid layer thickness, meibum quality, and meibomian gland expressibility. These outcomes were repeatedly improved in studies evaluating IPL, especially in controlled trials where IPL was used as an adjunct to meibomian gland expression.^{1,2,7} Improvements in subjective symptoms were also commonly reported, although symptom outcomes were less uniform than objective tear film and meibomian gland parameters. Some studies demonstrated greater symptom improvement in the IPL group than in the comparator group, whereas others reported improvement in both groups without consistent superiority across all symptom scales.^{2,4}

Mechanistic findings from the included studies suggest that IPL may also affect ocular surface inflammation. Reductions in tear inflammatory mediators, including IL-17A, IL-6, PGE2, IL-1 β , IL-17F, and MMP-9, were reported after IPL treatment or combined IPL therapy.^{5,12} These findings support the biological plausibility of IPL in MGD-related dry eye, although they should be considered supportive mechanistic evidence rather than definitive evidence of clinical effectiveness.

The safety profile of IPL was generally favorable across the included studies. Serious adverse events were not commonly reported, and most adverse effects were mild or transient. Reported events included pain or burning during treatment and an isolated case of partial eyelash loss.⁷ Overall, the available evidence suggests that IPL is a potentially effective and well-tolerated treatment for

meibomian gland dysfunction-related dry eye, particularly for improving tear film stability and meibomian gland-related outcomes. Nevertheless, because several studies evaluated IPL in combination with other interventions, the independent contribution of IPL should be interpreted in relation to the specific treatment protocol used.

Interpretation of Clinical Effectiveness

The clinical effectiveness of IPL in meibomian gland dysfunction-related dry eye appears to be most evident in outcomes directly related to evaporative dry eye physiology. Across the included studies, improvements in tear breakup time, non-invasive tear breakup time, lipid layer thickness, meibum quality, and gland expressibility were more consistent than improvements in subjective symptom scores. This pattern suggests that IPL may primarily act by improving tear film stability and meibomian gland function, while symptom improvement may be influenced by additional factors such as baseline disease severity, placebo effects, concurrent therapy, follow-up duration, and the symptom scale used.

Controlled studies provide the most relevant evidence for assessing clinical effectiveness. Trials comparing IPL plus meibomian gland expression with sham IPL plus meibomian gland expression generally showed greater improvement in objective outcomes in the IPL-treated groups, particularly TBUT, meibomian gland secretion, meibomian gland score, and meibum quality.^{2,7} Similarly, the study comparing IPL plus meibomian gland expression with meibomian gland expression alone reported superior improvements in tear film and meibomian gland parameters in the IPL combination group.¹ These findings indicate that IPL may provide additional clinical benefit beyond gland expression alone.

The effect of IPL on patient-reported symptoms was favorable but less consistent. Several studies reported reductions in OSDI, SPEED, SANDE, or other symptom scores after IPL treatment, indicating symptomatic improvement in many patients. However, not all controlled trials demonstrated clear superiority of IPL over comparator groups for every symptom measure. For instance, Toyos et al. reported greater improvement in Eye Dryness Score with IPL plus meibomian gland expression, but OSDI improved similarly in both IPL and control groups.² This inconsistency

suggests that symptom scores should be interpreted alongside objective clinical outcomes rather than as the sole indicator of treatment effectiveness.

The included studies also show that clinical effectiveness may depend on the treatment protocol. IPL delivered as a standalone therapy demonstrated improvements in symptoms and lipid layer-related outcomes in placebo-controlled evidence.⁶ Studies using IPL as an adjunct to meibomian gland expression frequently showed improvements in both tear film and gland-related parameters, while studies combining IPL with low-level light therapy also reported improvements in symptoms and TBUT.⁴ Therefore, the evidence supports IPL as an effective therapeutic modality, but the observed effect varies according to whether IPL is used alone or integrated into a combined treatment approach.

Overall, the clinical findings suggest that IPL is most effective for improving the evaporative component of MGD-related dry eye, particularly tear film instability and meibomian gland dysfunction. The evidence for symptomatic improvement is supportive, but less uniform than the evidence for objective functional improvement. This distinction is important when evaluating the overall effectiveness of IPL, because MGD-related dry eye is a condition in which subjective symptoms and objective signs do not always change in parallel.

Another important consideration is that the included studies evaluated IPL in different therapeutic contexts. Some studies assessed IPL as a standalone or IPL-dominant therapy, while others evaluated IPL combined with meibomian gland expression or low-level light therapy. Evidence from IPL-alone or IPL-dominant studies suggests that IPL may independently improve symptoms, lipid layer parameters, meibomian gland capping, and lid margin abnormalities.^{3,6,8,13} However, many studies with stronger improvements in tear breakup time, meibum quality, and gland expressibility used IPL in combination with meibomian gland expression or low-level light therapy.^{1,2,4,7,9} Therefore, the effectiveness observed in this review should be interpreted as evidence for IPL-based therapy, with caution in attributing all clinical improvements to IPL alone.

Interpretation of Tear Film and Meibomian Gland Outcomes

The tear film and meibomian gland outcomes provide the strongest and most consistent support for the effectiveness of IPL in meibomian gland dysfunction-related dry eye. Across the

included studies, IPL was repeatedly associated with improvement in tear film stability, particularly through increases in TBUT or NIBUT. Because MGD-related dry eye is primarily driven by lipid layer abnormality and tear hyper-evaporation, improvement in these parameters is directly relevant to the underlying disease mechanism.

The improvement in tear breakup time observed across several controlled studies suggests that IPL may contribute to a more stable tear film by enhancing meibomian gland secretion and improving the quality of the tear lipid layer. This is supported by studies reporting parallel improvements in meibum quality, gland expressibility, lipid layer thickness, and lid margin abnormalities after IPL treatment. In this context, the benefit of IPL appears to be closely linked to restoration of meibomian gland function rather than to increased aqueous tear production.^{1,2,7}

Findings related to Schirmer test further support this interpretation. Several studies showed that tear stability and gland-related outcomes improved even when Schirmer test results did not change substantially. This pattern indicates that IPL is more likely to improve the evaporative component of dry eye rather than directly stimulate aqueous tear secretion. Therefore, changes in TBUT, NIBUT, lipid layer thickness, and meibomian gland parameters may be more appropriate indicators of IPL response than Schirmer test in patients with MGD-related dry eye.^{4,11}

The consistency of meibomian gland-related improvements across studies is also clinically important. Improvements in meibomian gland yielding secretion score, meibomian gland score, meibum grade, expressible gland number, and gland capping suggest that IPL may improve both the quantity and quality of meibomian secretion. These changes may help explain the observed improvement in tear film stability. In studies where IPL was combined with meibomian gland expression, the combined approach may have enhanced gland clearance while IPL contributed thermal, vascular, or anti-inflammatory effects.^{2,6,7}

Meibography-related findings were less consistently improved than functional gland measures. This is expected because structural gland dropout may represent chronic or irreversible gland loss, whereas expressibility and meibum quality are more dynamic parameters. Therefore, IPL may produce measurable functional improvement without necessarily reversing established

anatomical gland dropout. This distinction is important when evaluating treatment response, especially in patients with long-standing or severe MGD.^{10,11}

Overall, the tear film and meibomian gland findings indicate that IPL is most relevant for patients whose dry eye symptoms are driven by evaporative dysfunction and impaired meibomian gland secretion. The available evidence suggests that the clinical value of IPL lies primarily in improving tear film stability, lipid layer function, and glandular secretion quality, rather than in modifying aqueous tear production or reversing advanced gland dropout.

Mechanistic Interpretation of IPL Therapy

The mechanistic findings from the included studies suggest that the effectiveness of IPL in meibomian gland dysfunction-related dry eye may involve more than a simple thermal effect on meibum. Although heat-related softening of obstructed meibum remains one plausible explanation for improved gland expressibility and tear film stability, the included biomarker and mechanistic studies indicate that IPL may also influence inflammatory, vascular, microbial, and cellular pathways relevant to MGD-related dry eye.

The clearest mechanistic evidence relates to ocular surface inflammation. Liu et al. reported significant reductions in tear IL-17A, IL-6, and PGE2 after IPL compared with sham treatment, while D'Souza et al. reported reductions in IL-1 β , IL-17F, MMP-9, and the MMP-9/TIMP-1 ratio after combined IPL and low-level light therapy.^{5,12} These findings suggest that IPL may help interrupt the inflammatory cycle associated with MGD, in which altered meibum, tear film instability, and ocular surface irritation reinforce one another. The reduction of inflammatory mediators is particularly relevant because inflammation contributes to both glandular dysfunction and ocular surface damage in evaporative dry eye.

A vascular mechanism may also contribute to the observed clinical effects. MGD is commonly associated with lid margin telangiectasia and abnormal periocular vascularity, and IPL is known to target hemoglobin-containing vessels through light absorption. Within the included studies, improvements in telangiectasia, lid margin vascularity, and related lid margin abnormalities were reported after IPL treatment.^{1,3} This supports the possibility that IPL may reduce abnormal vascular

sources of inflammatory mediators around the eyelid margin, thereby contributing to improved ocular surface homeostasis.

Microbial modulation may represent another supportive pathway. Xue et al. reported inhibited growth of *Corynebacterium macginleyi* after IPL therapy, alongside improvement in symptoms, lipid layer thickness, and meibomian gland capping.⁶ Although this finding does not establish microbial reduction as the primary mechanism of IPL, it suggests that changes in eyelid margin microbiology may accompany the clinical response to treatment.

The mechanistic findings also indicate that IPL-related effects may differ when combined with adjunctive light-based therapy. Chiang et al. reported changes in lower eyelid tissue flavin fluorescence after combined IPL and low-level light therapy, suggesting possible alteration in local cellular metabolic activity.⁹ Because this study compared combined IPL and low-level light therapy with low-level light therapy alone, the findings suggest that combined therapy may produce additional biological effects, although the separate contribution of IPL cannot be fully isolated from the low-level light therapy component.

Taken together, the included studies support a multifactorial mechanism for IPL in MGD-related dry eye. The observed improvements in tear film stability and gland function are likely related to a combination of meibum heating, improved gland expression, reduction of inflammatory mediators, modulation of abnormal eyelid vascularity, and possible changes in eyelid margin microbiology or tissue metabolism. However, because mechanistic outcomes were reported in only a subset of studies and were often secondary or exploratory, these findings should be interpreted as supportive explanations for clinical benefit rather than definitive proof of a single mechanism.

Safety Considerations

The safety findings across the included studies suggest that IPL is generally well tolerated in patients with meibomian gland dysfunction-related dry eye. Serious adverse events were not commonly reported, and most studies either reported no significant safety concerns or described only mild and transient adverse effects. This safety profile is clinically relevant because IPL is applied near the ocular surface and periocular skin, where inadequate protection or inappropriate treatment parameters could theoretically result in ocular or cutaneous complications.

The most frequently described treatment-related symptoms were mild pain, burning sensation, or discomfort during the procedure. Rong et al. reported mild pain and burning in several patients and one case of partial eyelash loss after IPL applied directly to the eyelids.⁷ These events indicate that although IPL is generally tolerable, direct eyelid application may require particularly careful ocular protection, patient selection, and procedural technique.

Several studies reported no serious ocular safety changes after IPL treatment. Arita et al. found no clinically relevant changes in visual acuity, intraocular pressure, lens opacity, or fundus condition after IPL combined with meibomian gland expression.¹ Vergés et al. reported no local ocular, periocular, or systemic complications after Thermoaeye Plus IPL, and Xue et al. reported no adverse events during the study period.^{3,6} Toyos et al. also reported no serious adverse events in a multicenter randomized trial.²

The available evidence also suggests that adverse events were not clearly higher with IPL than with comparator interventions. Yan and Wu reported no significant difference in adverse event incidence between IPL and conventional gland massage combined with hot compress, while Jiang et al. reported no significant difference in adverse events between the new-generation and traditional IPL devices.^{8,13} These findings support the short-term tolerability of IPL when administered under study protocols with appropriate safety precautions.

Despite these favorable findings, the safety evidence should be interpreted within the limits of the available studies. Follow-up duration was relatively short in several trials, and many studies excluded patients with darker Fitzpatrick skin types, photosensitivity, active ocular infection, recent ocular surgery, pigmented lesions in the treatment area, pregnancy, or other contraindications. Therefore, the current evidence is more informative for short-term safety in selected patients than for rare, delayed, or high-risk complications. Standardized reporting of adverse events, longer follow-up, and broader representation of different skin types would strengthen future safety evaluation of IPL for meibomian gland dysfunction-related dry eye.

Strengths and Limitations

A major strength of this systematic review is the inclusion of multiple clinical study designs, ranging from placebo-controlled and sham-controlled randomized trials to prospective comparative

studies and mechanistic clinical investigations. This allows the effectiveness of IPL to be examined from several complementary perspectives, including symptom response, tear film parameters, meibomian gland function, inflammatory biomarkers, and safety outcomes. The inclusion of studies evaluating IPL alone, IPL combined with meibomian gland expression, IPL combined with low-level light therapy, and different IPL devices also provides a broad overview of how IPL has been applied in meibomian gland dysfunction-related dry eye.

Another strength is that several included studies used controlled and masked designs, which improves confidence in the observed treatment effects. Placebo-controlled or sham-controlled studies are particularly important in dry eye research because subjective symptoms can be influenced by placebo effects, patient expectations, and concurrent supportive therapies. The presence of objective outcomes such as TBUT, NIBUT, lipid layer thickness, meibum quality, gland expressibility, and inflammatory markers also strengthens the assessment of IPL effectiveness beyond patient-reported symptoms alone.^{2,5,6}

However, several limitations should be acknowledged. First, the included studies were heterogeneous in treatment protocol, IPL device, number of sessions, treatment interval, treatment area, adjunctive procedures, and comparator type. Some studies evaluated IPL as a standalone intervention, while others used IPL with meibomian gland expression or low-level light therapy. This heterogeneity limits direct comparison across studies and prevents a clear estimation of the independent effect of IPL in all included evidence.

Second, the outcome measures were not standardized across studies. Although many studies assessed tear breakup time, symptoms, and meibomian gland function, the specific instruments and scoring systems differed. Symptom outcomes were measured using OSDI, SPEED, SANDE, Eye Dryness Score, or other symptom scales, while meibomian gland outcomes used different expressibility, secretion, and meibum quality grading systems. These differences limited the ability to pool findings quantitatively and required narrative synthesis.

Third, not all included studies had the same methodological strength. Several studies were uncontrolled, open-label, or single-arm prospective designs, which increases the possibility of confounding, placebo effects, regression to the mean, and measurement bias. Even among

randomized studies, some used active comparators without sham treatment, and some had limitations related to masking, sample size, or paired-eye design. Therefore, findings from lower-risk controlled studies should carry greater interpretive weight than findings from uncontrolled studies.

Fourth, the follow-up duration varied substantially, ranging from short-term assessment at 14 days to longer follow-up over several months. This makes it difficult to determine the durability of IPL effects across all protocols. While some studies reported sustained improvement, the available evidence remains limited for long-term recurrence, maintenance therapy, and delayed adverse events.

Finally, patient selection differed across studies, particularly in baseline MGD severity, skin type eligibility, use of concomitant therapy, and exclusion criteria. Many studies excluded patients with darker Fitzpatrick skin types or contraindications to IPL, which may limit generalizability to broader clinical populations. As a result, the findings are most applicable to selected patients who meet the safety criteria used in the included clinical studies.

Implications for Clinical Practice

The findings of this systematic review suggest that IPL may be considered a therapeutic option for patients with meibomian gland dysfunction-related dry eye, particularly when conventional measures such as artificial tears, lid hygiene, warm compresses, or manual gland expression provide insufficient improvement. The most consistent benefits were observed in tear film stability and meibomian gland-related outcomes, indicating that IPL may be most clinically relevant for patients with an evaporative dry eye profile and demonstrable meibomian gland dysfunction.

In clinical practice, IPL should be viewed primarily as a treatment targeting the evaporative and glandular components of dry eye rather than as a general treatment for all forms of dry eye disease. Patients with reduced tear breakup time, poor meibum quality, impaired gland expressibility, lid margin telangiectasia, plugging, or capping may be more appropriate candidates for IPL than patients whose symptoms are driven predominantly by aqueous tear deficiency. The limited or inconsistent changes in Schirmer test reported in several studies further support the need to select patients based on MGD-related evaporative features rather than tear production alone.^{4,11}

The evidence also indicates that IPL is frequently used as part of a combined treatment approach, especially with meibomian gland expression. In practice, this means that IPL may be

integrated with gland expression to enhance gland clearance and improve meibum quality. However, clinicians should recognize that when IPL is combined with adjunctive procedures, the observed clinical improvement may reflect the combined effect of the treatment protocol rather than IPL alone. This is particularly relevant when interpreting studies that used IPL with meibomian gland expression or low-level light therapy.^{1,2,12}

Safety considerations should remain central when applying IPL in clinical settings. The included studies generally reported favorable short-term tolerability, but most protocols used strict eligibility criteria and ocular protection. Therefore, careful screening for contraindications, appropriate Fitzpatrick skin type assessment, protection of the ocular surface, and adherence to device-specific treatment parameters are essential. Particular caution is needed when IPL is applied near or directly on the eyelids, as periocular discomfort and partial eyelash loss were reported in one direct-eyelid application study.⁷

Overall, the current evidence supports IPL as a useful adjunctive or procedural treatment for selected patients with MGD-related dry eye. Its clinical role appears strongest in improving tear film stability, meibomian gland function, and lipid layer-related abnormalities. Nevertheless, treatment decisions should be individualized according to disease severity, baseline gland function, skin type, contraindications, available device protocols, and patient expectations.

Recommendations for Future Research

Future research should prioritize well-designed randomized controlled trials that evaluate IPL as a clearly defined intervention in patients with meibomian gland dysfunction-related dry eye. Because many existing studies assessed IPL in combination with meibomian gland expression or low-level light therapy, further trials are needed to distinguish the independent effect of IPL from the effect of adjunctive procedures. Comparative studies with separate treatment arms for IPL alone, meibomian gland expression alone, combined IPL and meibomian gland expression, and sham treatment would provide clearer evidence regarding the specific contribution of IPL.

Standardization of treatment protocols is also needed. The included studies varied in IPL device, fluence, pulse pattern, number of treatment sessions, treatment interval, anatomical treatment area, and use of ocular protection. Future studies should report these parameters in detail and evaluate

whether different protocols produce different clinical outcomes. Direct comparisons between treatment schedules may help determine the optimal number of sessions, treatment interval, and maintenance strategy for sustained benefit.

Future studies should also use more consistent outcome measures. Core outcomes should include both patient-reported symptoms and objective indicators of MGD-related evaporative dry eye, such as TBUT or NIBUT, lipid layer thickness, meibomian gland expressibility, meibum quality, lid margin abnormalities, and ocular surface staining. Standardized measurement methods and uniform follow-up time points would improve comparability across studies and may allow future quantitative synthesis.

Longer follow-up is necessary to determine the durability of IPL effects. Several included studies reported short-term improvement, but evidence remains limited regarding recurrence, retreatment intervals, and long-term maintenance. Future trials should include follow-up beyond 6 months whenever possible, with specific evaluation of whether repeated or maintenance IPL sessions are required to preserve clinical benefit.

Further mechanistic studies are also warranted. Existing biomarker findings suggest that IPL may reduce ocular surface inflammation and influence vascular, microbial, or cellular metabolic pathways. However, these outcomes were assessed in only a limited number of studies. Future research should integrate clinical endpoints with tear inflammatory markers, meibum composition, eyelid margin vascularity, microbiological profiles, and imaging-based parameters to clarify how IPL improves MGD-related dry eye and which patients are most likely to respond.

Finally, future research should improve patient stratification and safety reporting. Studies should evaluate whether treatment response differs according to MGD severity, meibomian gland dropout, rosacea status, baseline inflammatory profile, age, sex, and Fitzpatrick skin type. Safety outcomes should be reported systematically, including ocular, periocular, dermatologic, and delayed adverse events. Broader inclusion of different skin types, while maintaining appropriate safety precautions, would help determine the generalizability of IPL therapy across diverse patient populations.

CONCLUSION

Current evidence suggests that intense pulsed light is an effective and generally well-tolerated treatment for meibomian gland dysfunction-related dry eye, particularly in improving tear film stability and meibomian gland function. Across the included studies, IPL was most consistently associated with improvements in tear breakup time, non-invasive tear breakup time, lipid layer parameters, meibum quality, gland expressibility, and lid margin abnormalities. Improvements in patient-reported symptoms were also frequently observed, although symptom outcomes were less consistent across controlled studies than objective tear film and gland-related measures.

The available evidence indicates that IPL is especially relevant for the evaporative component of dry eye associated with meibomian gland dysfunction. In contrast, parameters related to aqueous tear production, such as Schirmer test results, showed less consistent improvement. Mechanistic findings further suggest that IPL may contribute to clinical benefit through anti-inflammatory, vascular, microbial, and cellular effects, including reductions in tear inflammatory mediators and improvement in eyelid margin-related abnormalities.

Although the safety profile of IPL was generally favorable, most studies evaluated selected patient populations under controlled treatment protocols with defined contraindications and ocular protection. Therefore, careful patient selection and adherence to safety procedures remain essential. Because several included studies evaluated IPL in combination with meibomian gland expression or low-level light therapy, the independent effect of IPL should be interpreted cautiously. Further high-quality randomized trials with standardized IPL protocols, longer follow-up, consistent outcome measures, and systematic safety reporting are needed to define the optimal role of IPL in the management of meibomian gland dysfunction-related dry eye.

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