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Structural And Clinical Changes in Moderate to Severe Meibomian Gland Dysfunction After Intense Regulated Pulsed Light Therapy Using IDRA

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ABSTRACT

Purpose:

To evaluate the clinical and structural outcomes of Intense Regulated Pulsed Light (IRPL) therapy in patients with moderate to severe Meibomian Gland Dysfunction (MGD), using the IDRA Ocular Surface Analyzer as the primary assessment tool.

Methods:

This cohort study included 124 eyes of patients with moderate to severe MGD treated with three IRPL sessions over six weeks at Chaudhary Eye Centre & Laser Vision. Clinical parameters such as Tear Break-Up Time (TBUT), Non-Invasive Break-Up Time (NIBUT), Tear Meniscus Height (TMH), Lipid Layer Thickness (LLT), blink rate, and meibomian gland dropout were measured using the IDRA analyzer at baseline and after each session. A validated questionnaire was used post-treatment to assess symptom relief, satisfaction, and side effects. Data were analyzed using the Friedman test and Durbin-Conover post hoc comparisons.

Results:

Statistically significant improvements were observed in all clinical and structural parameters ($p < 0.001$). TBUT increased from 3–4 to over 12 seconds, NIBUT from 2.5 to 10.5 seconds, TMH from 0.105 to 0.433 mm, and LLT from 35 to over 83 nm. Blink rate normalized, and meibography revealed reduced gland dropout. Over 85% of patients reported moderate to complete symptom relief, and 54.84% reported high satisfaction. Side effects were minimal and self-resolving.

Conclusion:

IRPL therapy is an effective and well-tolerated intervention for moderate to severe MGD, providing substantial clinical and structural improvement. Maintenance sessions may be required to sustain long-term benefits.

Key Words: *Dry eye diseases, Intense Regulated Pulsed Light therapy, Meibomian Gland Dysfunction, Tear meniscus height, Lipid layer thickness, Tear Break Up Time*

1. INTRODUCTION

Dry Eye Disease (DED) is a complex, multifactorial disorder marked by the disruption of tear film homeostasis, ocular surface inflammation, and neurosensory dysfunction. It can be broadly classified into aqueous-deficient, evaporative, or mixed types based on the underlying pathophysiology.[1] Among these, Meibomian Gland Dysfunction (MGD) is a leading contributor to evaporative DED. This condition arises from obstructed, inflamed, or atrophic meibomian glands, resulting in deficient meibum secretion and increased tear evaporation, which destabilizes the tear film.[2] MGD can be further categorized based on the level of gland secretion—either low (due to hyposecretion or obstruction) or high (hypersecretion), with both primary and secondary causes contributing. For instance, mucus membrane pemphigoid is a secondary cause of cicatricial obstruction, while conditions like seborrheic dermatitis and acne rosacea are associated with both non-cicatricial obstruction and hypersecretion.[1,2]

Conventional management options for MGD, such as eyelid hygiene, warm compresses, lid massages, and artificial tears, primarily focus on symptomatic relief by promoting meibum flow and stabilizing the tear film.[3,4] Warm compresses soften the meibum to ease its expression, artificial tears temporarily supplement tear volume, and eyelid hygiene helps reduce inflammation-inducing debris and microbial load.[5] Despite these benefits, such therapies often fail to provide sustained improvement, particularly in cases with moderate to severe gland dysfunction.[6] In advanced stages where irreversible structural damage such as gland atrophy or chronic obstruction has occurred, conventional methods prove inadequate. Moreover, these approaches do not sufficiently address deeper pathological processes like chronic inflammation or meibocyte dysfunction, which are central to disease progression.[5,7]

Intense Regulated Pulsed Light (IRPL) has emerged as a non-invasive therapeutic modality targeting multiple underlying mechanisms of MGD. It involves the delivery of precisely regulated, polychromatic light pulses (500–1200 nm) to the periocular skin, where the light energy is absorbed by haemoglobin and melanin. This absorption generates heat, which melts thickened meibum, improves vascular function, reduces inflammation, and stimulates mitochondrial activity within the meibomian glands—thereby helping to restore gland functionality and improve tear film quality.[8–10]

The IDRA Ocular Surface Analyzer (SBM Sistemi, Italy) is an advanced diagnostic tool designed to provide a comprehensive evaluation of the ocular surface. It includes features such as non-invasive interferometry for lipid layer analysis, meibography for gland morphology, automated Tear meniscus height (TMH) measurement, and Non-invasive break-up time (NIBUT) testing. Lipid layer thickness (LLT) is determined by comparing interference patterns to a standardized grading scale, while NIBUT is measured by recording the time interval between a blink and the initial disruption of a projected grid on the cornea. TMH is automatically calculated to estimate tear volume.[11,12]

The present study aims to evaluate the structural and clinical effects of IRPL therapy in patients with moderate to severe MGD, utilizing the IDRA Analyzer as the primary assessment platform

2. METHODOLOGY

Study Design and Ethical Considerations

This cohort study was conducted involving 124 eyes at the department of Ophthalmology, Chaudhary Eye Centre & Laser Vision, from October 2023 to November 2024. Ethical approval was obtained from the Institutional Ethics Committee of Chaudhary Eye Centre & Laser Vision (No. EC008/0308/2024) prior to the commencement of the study. All procedure adhered to the tenets of the declaration of Helsinki, and patient confidentiality was strictly maintained throughout the study. Informed consent was obtained from all participants after explaining the purpose, procedures, and potential outcomes of the study.

Participants Selection

This study outlines the procedure for patient selection, pre sitting assessment, and post sitting assessment. It includes moderate to severe MGD patients aged 20 years to 45 years. Included participants underwent a comprehensive clinical evaluation including TBUT measurement and MGD Grading and a standardized IRPL treatment protocol comprising three sessions over six weeks. Clinical and structural changes were assessed at baseline before treatment and in 3 follow-up session using IDRA Ocular Surface Analyzer. Parameters evaluated included Eye Blink, NIBUT, TMH, LLT and Meibography and at final follow up, a questionnaire assessed patients' satisfaction, symptoms relief and side-effects. Patients with conditions ocular surface diseases such as Sjögren's syndrome or graft-versus-host disease or previous ocular or eyelid surgeries were excluded were excluded, as well as patients with a history of hypotensive drug use, prior IRPL therapy within the past 24 months. Furthermore, individuals who were pregnant or breastfeeding, those with known photosensitivity, and patients who failed to comply with follow-up visits were also excluded from participation in the study.

Pre- Session Procedure

All patients underwent comprehensive ophthalmic examinations, including best-corrected distance visual acuity evaluation measured using (Snellen chart), MGD was graded via (Haag Streit Slit-lamp biomicroscope) based on gland orifice plugging, lid margin irregularity, gland expressibility and secretion quality, each scored from 0 to 3, where 0 indicated normal findings, 1 indicated mild changes, 2 represented moderate signs including plugging, lid margin thickening, or cloudy secretions, and 3 reflects severe changes as complete orifice obstruction, lid margin and absent secretions. The total score from all four parameters yielding a range from 0 to 12, with scores of 5-8 classified as moderate MGD and ≥9 as severe MGD. TBUT was measured using fluorescein dye under cobalt blue illumination on slit- lamp biomicroscope. A TBUT >10 seconds was considered as normal, 5-10 seconds indicated mild instability, and <5 seconds reflected severe tear film instability. The structural parameters were assessed using the IDRA Ocular Surface analyzer (SBM Sistemi) provided non-invasive imaging of meibomian gland morphology, TMH, LLT, NIBUT and blink quality under standardized room conditions. All patients underwent first session of IRPL therapy at baseline using IRPL device(E>Eye). The treatment was applied to periocular area following the manufacturer's protocol, targeting the lower eyelid region from one temporal side to the other under a standard

room condition by a trained operator, ensuring eye protection with opaque goggles during the procedure.

Post- Session Procedure

Post–session evaluation was conducted at 15, 45, and 75 days, corresponding to each follow-up after IRPL sessions. At each visit, patients underwent a comprehensive ophthalmic examination, including TBUT measurement using fluorescein dye under cobalt blue filter illumination on (slit- lamp biomicroscope) to assess changes in tear film stability. Structural parameters were reassessed using the IDRA Ocular Surface analyzer, (SBM Sistemi) provided non-invasive imaging of meibomian gland morphology, TMH, LLT, NIBUT and blink quality under standardized room conditions. Each IRPL session was specifically designed with a 15 days gap after each session, ensuring a complete assessment of both clinical and structural improvements up to day 75. On the final day of follow-up patients also completed a questionnaire to evaluate satisfaction, symptoms relief after therapy and side effects.

Questionnaire Design and Validation

A structured questionnaire was developed to assess patient satisfaction, symptom relief, and side effects following IRPL therapy for MGD. It included both qualitative and quantitative questions using multiple-choice and Likert scales, focusing on symptom improvement, treatment experience, and adverse effects. The questionnaire was validated through expert review and pilot testing, with high internal consistency (Cronbach's alpha = 0.9). It was administered to patients after the third IRPL session in a clinical setting. Data were organized in Excel and analyzed under three domains: symptom relief, satisfaction and perceived benefit, and adverse effects.

Data Analysis

Statistical analysis was performed using R version 4.4.2. charts were drawn using Microsoft office -Excel 365. The Friedman Test was applied to assess significant differences across the multiple IRPL therapy sessions due to repeated measures and non-normal data distribution. Post-hoc analysis using the Durbin-Conover test was performed to identify significant improvements between individual treatment sessions (pre-treatment, post-first, second, and third sessions).

3. RESULT

The study sample consisted of 62 participants with a higher proportion of females compare to males. Specifically, there were 33 females, with a mean age of 29.9 ± 8.0 years, a median age of 28 years, and an age range from 20 to 45 years. On slit-lamp examination, 54.84% of eyes were diagnosed with moderate MGD, defined as a total score ranging from 5 to 8, while 45.16% were diagnosed with severe MGD, defined as a total score of 9 or higher, as shown in Figure 1.

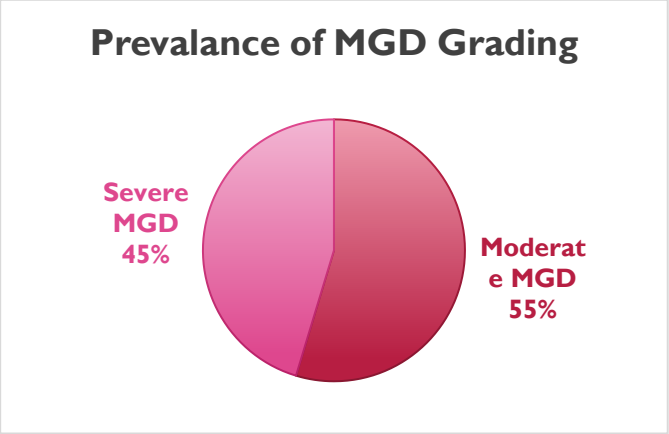

Figure 1: Prevalence of MGD Grading

The Friedman test demonstrated statistically significant improvements in all evaluated clinical and structural parameters following IRPL therapy in patients with moderate to severe MGD (χ^2 range = 175–186, $p < 0.001$). TTBUT showed a notable increase in median (IQR) values improved from 3.0(0.78) seconds to 12.0(0.05) seconds in the right eye and from 4.0(0.15) to 12.0(0.07) seconds in the left eye. Pairwise comparisons using the Durbin-Conover test confirmed a consistent and statistically significant improvement after each treatment session ($p < 0.001$). Blink rate percentage also improved significantly over time ($\chi^2 = 183$, $p < 0.001$), with values increasing from 34.7 ± 1.5 to 82.8 ± 3.38% in right eye and from 35.8 ± 4.75 to 84.5 ± 3.88% in left eye, suggesting normalization of blink patterns, which supports better ocular surface protection. NIBUT exhibited significant increases across sessions ($\chi^2 = 184–185$, $p < 0.001$), with median (IQR) values rising from 2.6(0.72) to 10.1(0.67) seconds in right eye and from 2.45(0.51) to 10.55(0.45) seconds in left eye, reinforcing improved tear film stability through a non-invasive modality. TMH analysis revealed statistically significant increases post-treatment

(χ^2 = 184–185, $p < 0.001$), with values increasing from 0.105 ± 0.02 to 0.385 ± 0.01 mm in right eye and from 0.13± 0.01 to 0.433 ± 0.02 mm to in left eye, potentially reflecting enhanced tear volume. LLT also showed substantial enhancement (χ^2 = 182–183, $p < 0.001$), with values improving from 35.5 ± 3.13 to 83.0 ± 1.25 nm in right eye and from 34.1 ± 3.88 to 83.8 ± 2.75 nm in left eye, indicative of better lipid secretion and reduced tear evaporation. Furthermore, meibography findings demonstrated significant structural improvement, with median (IQR) values lower lid gland dropout decreasing from 87.0(2.55) to 32.0(4.5) % and upper lid dropout from 88.5(2.65) to 35.0(3.75) % in OD and from 87.0(3.45) to 32.0(2.1) % and UL from 89.2(2.85) to 34.0(3.2) % in OS (χ^2 = 182–186, $p < 0.001$), as supported by Durbin-Conover post hoc analysis ($p < 0.001$).

These changes, as summarized in Figure 1 and 2, underscore the therapeutic efficacy of IRPL therapy in improving both clinical function and structural integrity in patients with moderate to severe MGD. Collectively, these results underscore the therapeutic efficacy of IRPL therapy in improving both clinical symptoms and structural integrity in moderate to severe MGD. The line graphs illustrates the progressive improvement of ocular surface parameters in both the right eye and left eye following IRPL therapy. Across the treatment milestones pre, 1st sitting, 2nd sitting, and 3rd sitting, there is a consistent upward trend in TBUT, NIBUT, TMH, LLT and Blink rate. The parallel progression in both eyes supports the efficacy of IRPL in improving both clinical and structural parameters in moderate to severe MGD- associated dry eye disease.

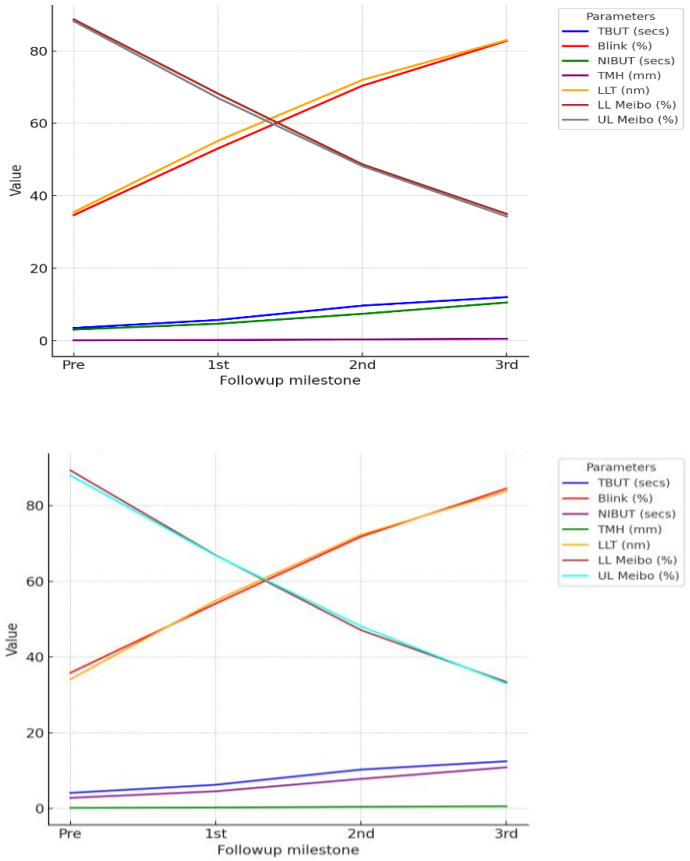

Figure 2: Trend of Improvement in clinical parameters in A: Right Eye B: Left Eye

Pigmentation was initially noted in 1.61% of participants and resolved entirely in subsequent sessions. Skin patches were observed in 4.84% of cases at the beginning, reduced to 1.61%, but later increased to 11.29%, suggesting a mild recurrence (Figure 3). In terms of therapeutic outcomes, the proportion of patients reporting complete relief declined from 67.74% after the first session to 46.77% by the third. Meanwhile, reports of moderate relief increased from 27.42% to 45.16%, indicating a shift from full to partial improvement over time. Minimal or no relief remained low but showed a slight upward trend, suggesting a gradual reduction in overall treatment efficacy (Figure 4). Despite this, a majority of respondents (54.84%) expressed high satisfaction with the IRPL therapy (Figure 5).

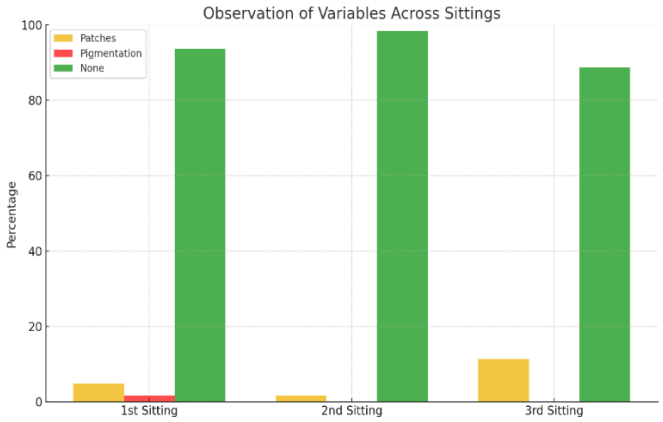

Figure 3: Prevalence of IRPL Complications over time

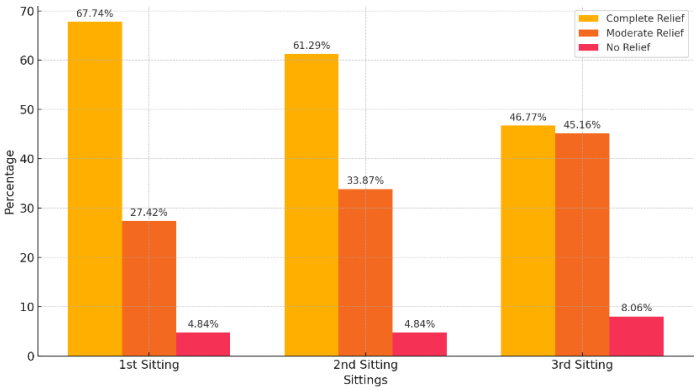

Figure 4: Relief in symptoms across each sitting

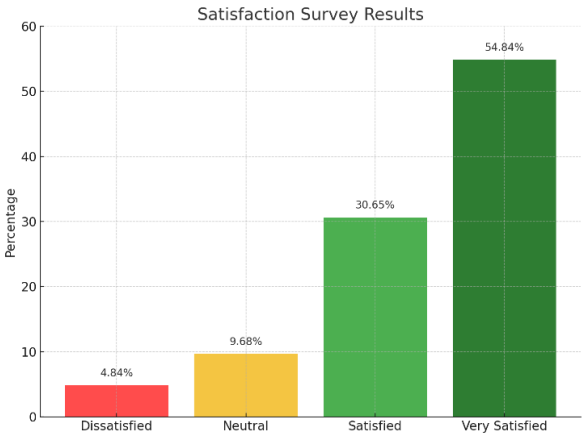

Figure 5: Overall satisfaction level with IRPL Therapy

4. DISCUSSION

The average Tear Break-Up Time (TBUT) showed a significant increase from a baseline of 3–4 seconds to over 12 seconds following IRPL therapy, indicating improved tear film stability and reduced evaporative loss. These outcomes are consistent with earlier studies by Arita et al. and Vegunta et al., where TBUT improvements were also noted post-IRPL in patients with MGD. Arita et al. reported an increase from 4.2 to 10.1 seconds, while Vegunta et al. observed TBUT values exceeding 11 seconds post-treatment.[12,13] Similarly, the NIBUT improved to beyond 10 seconds, further supporting IRPL's positive impact on tear film integrity, aligning with the findings of these studies.

The increase in TMH observed in this study may reflect either enhanced aqueous retention or reduced tear evaporation, likely due to restoration of the lipid layer. This observation supports the role of IRPL in lipid barrier recovery. Finis et al. similarly reported that IRPL significantly improved TMH in MGD patients by enhancing lipid layer integrity, which in turn minimized evaporative loss and promoted tear retention.[14] In addition, a near threefold increase in LLT was recorded post-treatment, reflecting enhanced meibomian gland activity. These findings align with the conclusions drawn by Craig et al., who emphasized LLT's role in maintaining tear film stability and preventing evaporative dry eye.[1] Collectively, these results reinforce the hypothesis that IRPL not only improves glandular output but also restores the functional balance among tear film layers, establishing its efficacy in moderate to severe MGD management.[15]

Meibography findings revealed a noticeable reduction in meibomian gland dropout percentages post-IRPL, suggesting potential recovery or preservation of glandular structure, likely influenced by IRPL's photobiomodulatory properties. Similar outcomes were described by Dell et al., who attributed improved gland structure to enhanced mitochondrial function and tissue repair mechanisms activated by IRPL.[8] Toyos et al. further proposed that IRPL alleviates local inflammation, thereby reducing chronic damage contributing to gland atrophy in MGD.[16] These observations support the regenerative potential of IRPL in stabilizing both tear film dynamics and glandular architecture, as corroborated by previous research.[17]

Blink rates also showed significant improvement after IRPL therapy, supporting more effective tear film distribution. Incomplete blinking—exacerbated by prolonged screen use—is a known contributor to evaporative dry eye. Koh S et al. demonstrated a 25–30% increase in complete blinks post-IRPL, which correlated with improved tear film stability.[18] The current findings are consistent with this, as normalized blink patterns were observed post-treatment, likely aiding lipid layer distribution and ocular surface protection.[19] From a patient-reported perspective, over 85% experienced either complete or moderate symptomatic relief after IRPL. Although the rate of complete relief slightly declined by the third session, an increase in moderate relief was noted, reflecting sustained or gradually improving therapeutic benefit. Similar outcomes were noted by Wu Y et al., where 78% of participants reported symptom relief, particularly in activities such as reading and screen use, often impacted by blinking inefficiencies and environmental stress.[20]

The treatment was well tolerated, with only 16.1% of patients reporting mild, transient discomfort and no serious adverse events. This aligns with the safety profile described by Toyos et al., where fewer than 20% of patients experienced minor side effects such as warmth or redness, and no significant complications occurred.[16] Comparable findings were documented in other studies, with fewer than 15% of participants reporting minimal discomfort, further supporting IRPL's excellent tolerability.[8,21,22] Prior research also supports the safety and efficacy of newer IPL devices in managing dry eye disease associated with MGD, with clinical improvements noted within two weeks of treatment initiation and sustained up to 23 weeks post-therapy.[23] In this study, early pigmentation was observed in 1.61% of participants but resolved completely by subsequent visits. Patches were initially seen in 4.84%, declined to 1.61%, and later recurred slightly at 11.29%, indicating only minor and non-serious recurrence of cutaneous effects.

Despite the positive findings, certain limitations should be acknowledged, including the lack of a control group and relatively short follow-up duration. Future randomized controlled trials with extended observation periods are recommended to validate the durability of therapeutic effects and to determine the most effective IRPL treatment intervals.

5. CONCLUSION

IRPL therapy significantly improves tear film stability, meibomian gland structure, and ocular comfort in patients with moderate to severe MGD. These findings advocate for its inclusion in comprehensive DED management strategies, particularly in screen-exposed populations. However, the progressive stabilization experienced after the therapy suggests that maintenance sessions might extend the long-term benefits.

Declaration of Interest and disclosure: The authors have nothing to disclose.

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