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Effect of Photodynamic Therapy Using Lasers on Periodontal Parameters in Patients with Chronic Periodontitis

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ABSTRACT

Background: Chronic periodontitis is a widespread inflammatory disease characterized by the destruction of supporting periodontal tissues, primarily driven by pathogenic microbial biofilms. While conventional scaling and root planing (SRP) is the cornerstone of treatment, its limitations in eradicating bacteria from complex anatomical sites necessitate adjunctive therapies. Antimicrobial photodynamic therapy (aPDT) offers a promising non-invasive approach, utilizing a photosensitizer activated by a specific light wavelength to generate reactive oxygen species, thereby targeting periodontopathogenicbacteria.This study aims to assess and compare the changes in probing pocket depth (PD) and clinical attachment level (CAL), following SRP alone versus SRP combined with antimicrobial photodynamic therapy using an 810 nm diode laser and Indocyanine Green (ICG) in patients with chronic periodontitis.

Materials and Methods:A total of 42 systemically healthy patients diagnosed with moderate to severe chronic periodontitis (probing pocket depth ≥5mm) were recruited from the Outpatient Department of Periodontology, Seema Dental College and Hospital, Rishikesh, Uttarakhand. Participants were randomly assigned to two groups (n=21 each): Group A (Control Group) which received SRP alone, and Group B (Test Group) which received SRP followed by aPDT. For Group B, a 5mg/ml ICG solution was prepared and applied into the periodontal pockets, followed by irradiation with an 810 nm diode laser. Clinical parameters including Gingival Index, Plaque Index, Sulcus Bleeding Index, Probing Depth, and Periodontal Clinical Attachment Loss were assessed at baseline and 3 months post-treatment. All collected data was statistically evaluated.

Results:The adjunctive use of laser-assisted aPDTlead to a statistically significant reduction in probing pocket depth and an improvement in clinical attachment level compared to SRP alone. This is based on previous research indicating that aPDT enhances the antimicrobial effects of SRP and contributes to the resolution of inflammation.

Conclusion: This study provides evidence on the efficacy of laser-assisted photodynamic therapy as a valuable adjunct to conventional non-surgical periodontal treatment for chronic periodontitis, potentially leading to improved clinical outcomes and patient comfort.

Keywords: *Chronic periodontitis, indocyanine green, laser, photodynamic therapy.*

1. INTRODUCTION

Periodontitis is a chronic inflammatory disease affecting the supporting structures of the teeth, including the periodontal ligament and alveolar bone. It is primarily initiated by a dysbiosis in the subgingival microbial biofilm, favoring anaerobic gram-negative bacteria, which triggers a host inflammatory response. Untreated, this progressive condition can lead to halitosis, gingival recession, tooth mobility, and ultimately, tooth loss, significantly impacting a patient's quality of life.Scaling and root planing (SRP) is the established gold standard for non-surgical periodontal therapy. However, mechanical debridement alone has limitations, particularly in reaching and decontaminating deep pockets, root furcations, and surface irregularities. The infectious nature of periodontitis necessitates approaches that can effectively reduce or eradicate pathogenic bacteria residing within biofilms and periodontal tissues.

Antimicrobial photodynamic therapy (aPDT) has emerged as a promising adjunctive therapeutic modality. This minimally invasive technique relies on three key components: a light source (such as a laser), a photosensitizer, and oxygen. When the photosensitizer, applied to the target site, is irradiated by light of a specific wavelength, it generates highly reactive oxygen species (ROS). These ROS exert a potent bactericidal effect by damaging microbial cell membranes and intracellular components, leading to bacterial inactivation. A significant advantage of aPDT is the reduced likelihood of microbial resistance development compared to conventional antibiotics [1].Indocyanine Green (ICG) is a photosensitizer that has gained considerable attention in periodontal aPDT. ICG is a non-toxic dye, approved by the FDA for clinical use, known for its rapid tissue penetration and absorption spectrum between 600nm and 900nm, making it compatible with diode lasers [2]. Diode lasers, in addition to activating photosensitizers, are also recognized for their ability to promote tissue healing and reduce edema, inflammation, and pain [3]. Given the potential of aPDT to improve periodontal outcomes, this study aims to specifically evaluate the effect of photodynamic therapy using an 810 nm diode laser and Indocyanine Green on key periodontal parameters, including probing pocket depth, sulcus bleeding index and clinical attachment level in patients with chronic periodontitis.

2. MATERIALS AND METHODS

This clinical study was conducted at the Outpatient Department (OPD) of the Department of Periodontology. Ethical clearance for the study was obtained from the institutional ethical committee.

- **Inclusion Criteria:**
  - Systemically healthy patients.
  - Patients diagnosed with moderate to severe chronic periodontitis.
  - Presence of probing pocket depth (PD) of ≥5mm.
  - Patients maintaining good oral hygiene.
  - Patients willing to participate and provide informed consent.
- **Exclusion Criteria:**
  - Smokers and tobacco users.
  - History of antibiotic therapy, anti-inflammatory therapy, or any periodontal treatment within the last 3 months.
  - Pregnant and lactating females.

Sample Size and Randomization:A total of 42 patients fulfilling the inclusion criteria were recruited for the study. These patients were randomly assigned into two groups, with 21 patients in each group.

Treatment Groups:

- **Group A (Control Group):**Patients in this group received conventional non-surgical periodontal treatment, which includes ultrasonic scaling and root planing (SRP) in one session.
- **Group B (Test Group):**Patients in this group received SRP in one session, followed by Antimicrobial Photodynamic Therapy (aPDT) using Indocyanine Green (ICG) and diode laser.

Preparation of Indocyanine Green (ICG) Solution:ICG (Aurogreen, Aurolabs, Madurai, India) was dissolved in 5ml of

sterile water to prepare an initial 5mg/ml ICG stock solution. This stock solution was then be further diluted in saline solution in a ratio of 1:5 to achieve a final concentration of 5mg/ml for clinical application. [Fig 1C, 3B]

Treatment protocol: All patients in both Group A and Group B underwent thorough ultrasonic scaling and root planing in a single session to remove supragingival and subgingival plaque and calculus. [Fig 1B] Following SRP, all patients received detailed instructions on proper tooth brushing techniques.After SRP, the prepared 5mg/ml ICG solution was carefully applied into the periodontal pockets of the test sites in Group B. [Fig 3B, 3C]The ICG was allowed an incubation period within the pockets to facilitate its uptake by the microbial biofilm.Subsequently, the ICG was activated by an 810 nm diodelaser. [Fig 3D]

Fig 1A: Armamentarium And Materials

Fig1B: Ultrasonic Scaler

Fig 1C: Preparation of Indocyanine Green

Fig 1D: Diode Laser

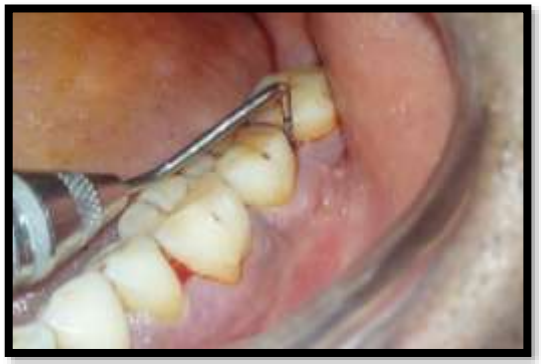


Fig 2A: Baseline (Pre-Operative Group A)

Fig 2B: Group A at 1 Month

Fig 2C: Group A at 3 Months

Fig 3A: Baseline (Pre-Operative Group B)

Fig 3B: Freshly Prepared Indocyanine Green Dye to Be Used in Group B

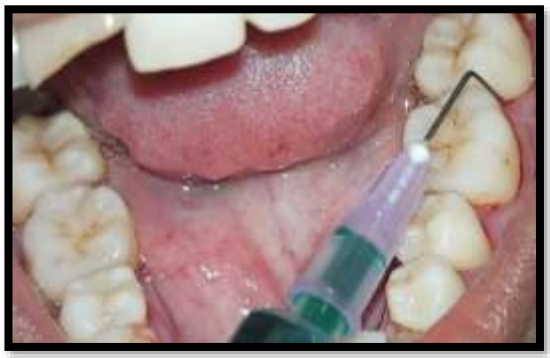


Fig 3C: Administration Of Indocyanine Green in Group B

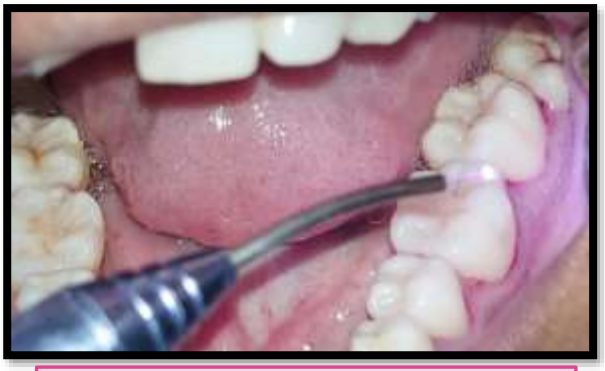


Fig 3D: Use Of Diode Laser in Activation of Photosensitizer in Group B

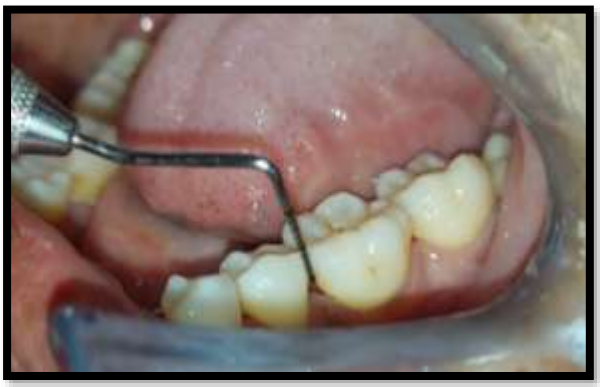


Fig 3E: Group B at 1 Month

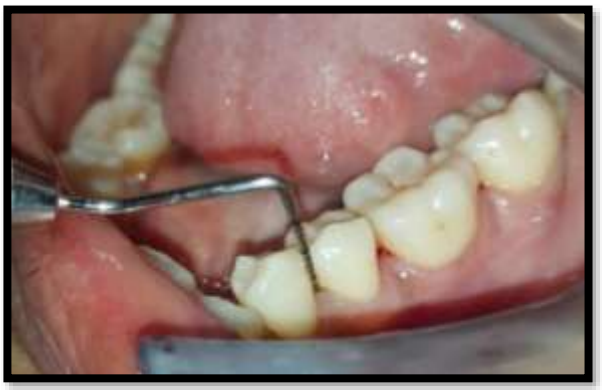


Fig 3F: Group B at 3 Months

The following clinical parameters were assessed at baseline, at 1 month and after 3 months post-treatment:Gingival Index (Loe and Silness 1963), Plaque Index (Silness and Loe 1964), Sulcus Bleeding Index (Muhlemann 1971), Probing Depth (PD), Clinical Attachment Level (CAL).

Statistical analysis: Data was entered into Microsoft Excel spreadsheet and was checked for any discrepancies. The data was analyzed by SPSS (21.0 version). Shapiro Wilk test was used to check which all variables were following normal distribution. Data was normally distributed, therefore, inferential statistics were performed using the parametric test. For intergroup comparison, independent t-test was used. Level of statistical significance was set at p-value less than 0.05(*).

3. RESULTS

Table 1: Depicts values of gingival index, plaque index and sulcus bleeding index at baseline, 1 month and 3 months of Group A and Group B

GINGIVAL INDEX (GI)	**TIME INTERVAL**	**GROUP A**	**GROUP B**
	BASELINE	1.319 ± 0.24	1.429 ± 0.27
	1 MONTH	1.219 ±0.18	1.138 ± 0.13
	3 MONTHS	1.176 ± 0.15	1.010 ± 0.07
PLAQUE INDEX (PI)	**BASELINE**	1.581±0.31	1.724±0.40
	1 MONTH	1.414±0.29	1.190±0.31
	3 MONTHS	1.329±0.27	1.052±0.20
SULCUS BLEEDING INDEX (SBI)	**BASELINE**	1.857±0.51	2.176±0.50
	1 MONTH	1.700±0.45	1.195±0.32
	3 MONTHS	1.581±0.42	1.081±0.27

Gingival Index(GI)

Table2–IntergroupcomparisonofGIintestandcontrol group in baseline and 3 months

GROUPS	**Time Interval**	**Mean Difference± Std. Deviation**	**P value**
GROUP A (Control)	Baseline to 1 month	0.100±0.104	0.002
GROUP B (Test)		0.295±0.052	
GROUP A (Control)	Baseline to 3 months	0.142±0.143	0.001
GROUP B (Test)		0.419±0.282	

IndependentT-test.p-Value≤ 0.05– statistically significant.

Table 2 shows the mean difference of Gingival Index from baseline to 1 month in Group A, which was **0.100 ± 0.104** and in Group B was **0.295±0.052**. The mean difference of Gingival Index from baseline to 3 months in Group A was **0.142 ± 0.143** and in Group B was **0.419 ± 0.282.**On Intergroup comparison, the decrease in GI was more in Group B as compared to Group A which was statistically significant from baseline to 1 month (p=0.002) and from baseline to 3 months (p=0.001).

Plaque Index(PI)

Table3–IntergroupcomparisonofPIintestandcontrol group in baseline and 3 months

GROUPS	Time Interval	Mean ± Std. Deviation	P value
GROUP A (Control)	Baseline to 1 month	0.166±0.123	0.003
GROUP B (Test)		0.533±0.514	
GROUP A (Control)	Baseline to 3 months	0.252±0.172	0.001
GROUP B (Test)		0.671±0.460	

IndependentT-test.p-Value≤ 0.05– statistically significant.

Table 3 shows the mean difference of Plaque Index from baseline to 1 month in Group A, which was 0.166±0.123 and in Group B was 0.533±0.514. The mean difference of Plaque Index from baseline to 3 months in Group A was 0.252±0.172 and in Group B was 0.671±0.460**.**On Intergroup comparison, the decrease in Plaque Index was more in Group B as compared to Group A which was statistically significant from baseline to 1 month (p=0.003) and from baseline to 3 months (p=0.001).

Sulcus Bleeding Index(SBI)

Table4–IntergroupcomparisonofSBIntestandcontrol group in baseline and 3 months

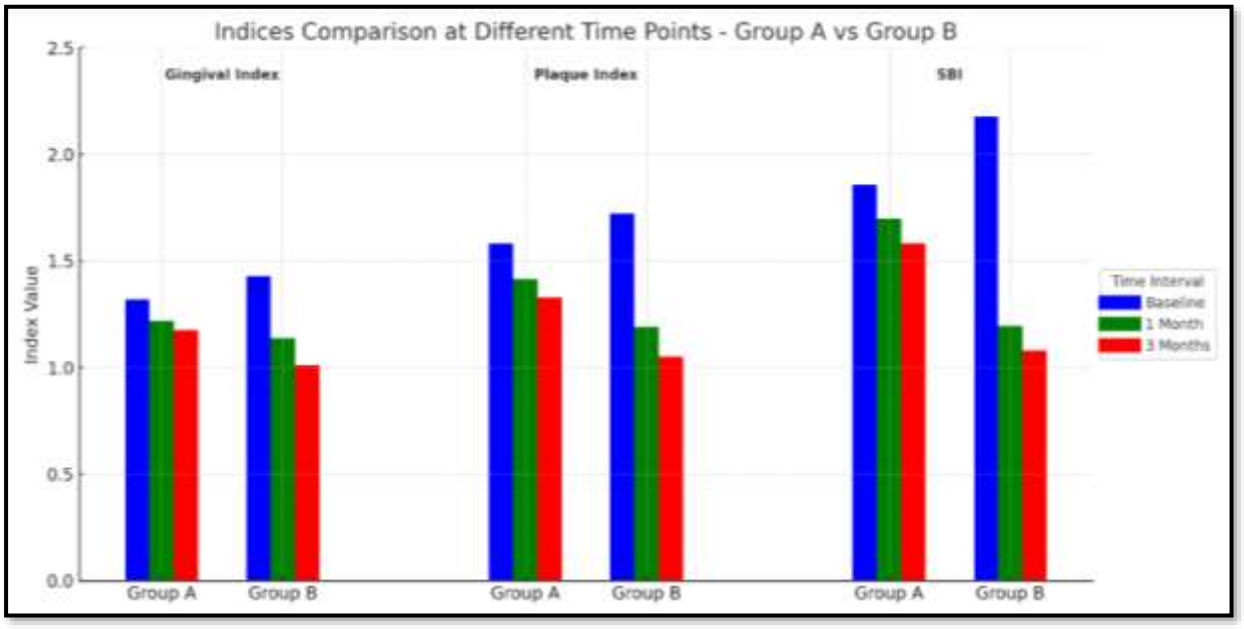
GROUPS	Time Interval	Mean ± Std. Deviation	P value
GROUP A (Control)	Baseline to 1 month	0.157±0.174	0.001
GROUP B (Test)		0.981±0.362	
GROUP A (Control)	Baseline to 3 months	0.276±0.234	0.001
GROUP B (Test)		1.095±0.404	

IndependentT-test.p-Value≤ 0.05– statistically significant.

Table 4 shows the mean difference of Sulcus Bleeding Index from baseline to 1 month in Group A which was 0.157±0.174 and in Group B was 0.981±0.362. The mean difference of Sulcus Bleeding Index from baseline to 3 months in Group A was 0.276±0.234 and in Group B was 1.095±0.404**.**On Intergroup comparison, the reduction in the values of Sulcus Bleeding

Index was more in Group B as compared to Group A which was statistically significant from baseline to 1 month (p=0.001) and from baseline to 3 months (p=0.001).

Graph 1–Comparison of Gingival Index, Plaque Index and Sulcus Bleeding Index of both the groups at all time intervals



Probing Pocket Depth(PPD)

Table5–IntergroupcomparisonofPPDintestandcontrol group in baseline and 3 months

GROUPS	Time Interval	Mean ± Std. Deviation	P value
GROUP A (Control)	Baseline to 1 month	0.081±0.321	0.001
GROUP B (Test)		1.25±0.584	
GROUP A (Control)	Baseline to 3 months	0.085±0.628	0.001
GROUP B (Test)		1.747±0.799	

IndependentT-test.p-Value≤ 0.05– statistically significant.

Graph2-Intergroupcomparisonof PPD intestandcontrol group in baseline, 1 month and 3 months

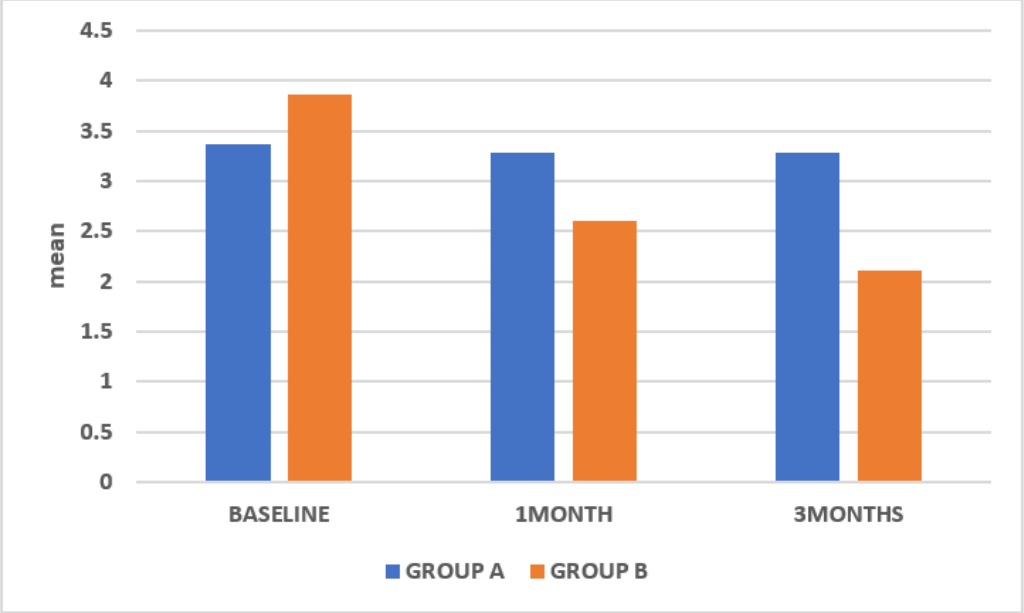


Table 5, Graph 2 shows the mean difference of Probing Pocket Depth from baseline to 1 month in Group A which was **0.081±0.321** and in Group B was **1.25±0.584**. The mean difference of Probing Pocket Depth from baseline to 3 months in Group A was **0.085±0.628** and in Group B was **1.747±0.799.**On Intergroup comparison, the reduction in PPD from baseline to 3 months was more in Group B than Group A, which was statistically significant (p=0.001).

Clinical Attachment Level(CAL)

Table6–IntergroupcomparisonofCALintestandcontrol group in baseline and 3 months

GROUPS	**Time Interval**	**Mean ± Std. Deviation**	**P value**
GROUP A (Control)	Baseline to 1 month	0.081±0.321	0.001
GROUP B (Test)		1.25±0.584	
GROUP A (Control)	Baseline to 3 months	0.085±0.628	0.001
GROUP B (Test)		1.747±0.801	

IndependentT-test.p-Value≤ 0.05– statistically significant.

Graph3-Intergroupcomparisonof CAL intestandcontrol group in baseline, 1 month and 3 months

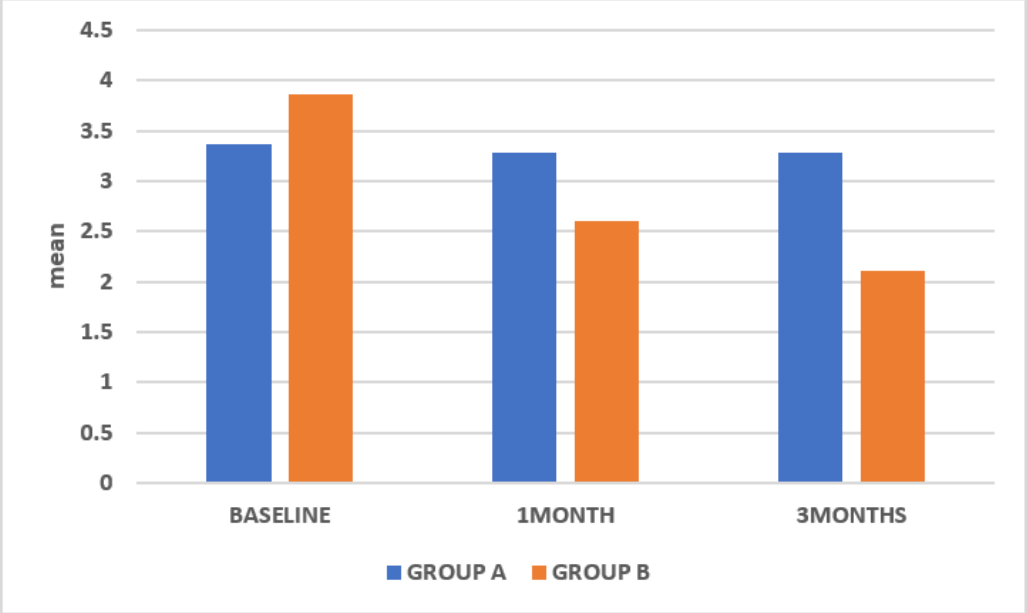


Table 6, Graph 3 shows the mean difference of Clinical Attachment Level from baseline to 1 month in Group A which was **0.081±0.321** and in Group B was **1.25±0.584**. The mean difference of Clinical Attachment Level from baseline to 3 months in Group A was **0.085±0.628** and in Group B was **1.747±0.801.**On Intergroup comparison, the gain in CAL from baseline to 3 months was more in Group B than Group A, which was statistically significant (p=0.001).

4. DISCUSSION

The initiation of periodontal disease is principally attributed to dental plaque. Disruption of microbial homeostasis, characterized by increased plaque aggregation, elicits a destructive immuno-inflammatory response from the host.A fundamental challenge in periodontal treatment lies in preventing the re-establishment of bacterial populations from any residual organisms that may persist in periodontal pockets or tissues following physical cleaning. Nonsurgical treatment, including oral hygiene instruction, plaque and calculus removal, and root surface mechanical cleaning is the established first line of defense. [4,5]

Consequently, antimicrobial photodynamic therapy is being used as a newer treatment option for patients with chronic periodontitis and patients with medical problems because it does not cause side effects, drug reactions, or antibiotic resistance. A photosensitizer, a substance that becomes active when exposed to light, binds to target cells and is then activated by light of a particular wavelength. This activation results in the creation of very reactive agents, including singlet oxygen, which are highly damaging to specific cells and bacteria. Photodynamic therapy provides an easily administered antibacterial treatment, particularly beneficial in areas with limited accessibility for mechanical cleaning, such as those with complex root anatomy and where bacteria may remain. [6,7]

Photosensitizers with antimicrobial properties, such as porphyrins, phthalocyanines, and positively charged phenothiazines like toluidine blue O and methylene blue, exhibit broad-spectrum antibacterial activity. Their positive charge facilitates binding to bacterial membranes, causing localized damage and enhancing penetration. Consequently, these photosensitizers are effective against both gram-negative and gram-positive bacteria, making toluidine blue O and methylene blue common choices for oral antibacterial photodynamic therapy.Recently, special attention has been paid to indocyanine green, as a product with photosensitizing potential. Indocyanine green (ICG) shows promise in combating periodontal bacteria, specifically *Aggregatibacteractinomycetemcomitans* and *Porphyromonas gingivalis,* when exposed to 810nm diode laser light. As an FDA-approved dye widely used in medical diagnostics, ICG's strong absorption of infrared light, particularly at 810nm, aligns perfectly with diode laser emissions [6].

Previous studies have explored the efficacy of aPDT with ICG and diode lasers as an adjunct to SRP in chronic periodontitis. Research by **Chandra, R. V., et al. (2015)[8]** and **Vangipuram P et al. (2021)[9]** concluded that laser-activated ICG can enhance the benefits of SRP. Studies by **Birang R et al. (2015)[10]**and **Shingnapurkar S et al. (2016)[11]**also reported significant short-term benefits and improved clinical outcomes with adjunctive PDT. While some studies, like **Monzavi A**

et al. (2016)[12], noted significant reductions in pocket depth and inflammation, they did not always find additional advantages in clinical attachment gain or plaque score. However, **Sukumar K et al. (2020)[13],** demonstrated a significant reduction in periodontal pathogens with multiple applications of PDT.

In the present study, both groups showed significant reductions in GI from baseline to 3 months. However, Group B exhibited greater reductions, with highly significant differences between baseline to 1 month and baseline to 3 months. On intergroup comparison, Group B demonstrated a significantly lower GI as compared to Group A after 3 months, indicating better gingival health improvement.

At baseline, no significant difference in PI scores was noticed between the groups. Both the groups showed significant reductions over time. However, Group B showed significantly lower PI scores after 3 months, suggesting better plaque control.

Both the groups showed significant reduction in SBI at all time points indicating progressive improvement. While Group B exhibited even more pronounced reduction with highly significant difference at all time points reflecting substantial improvement in gingival health. On intergroup comparison, a statistically significant reduction was seen at 1 month and 3 months in Group B despite of having slightly higher SBI at baseline indicating better improvement in gingival bleeding.

This is in accordance to the studies by **Betsy J et al (2014)[14],Srikanth K et al (2015)[8]and Agarwal P et al (2025)[7]**where significant reduction in gingival index, plaque index and sulcus bleeding index in PDT treated group was seen when compared with the SRP group. This change was attributed to the reduction in the inflammation and bacterial load achieved by antimicrobial Photodynamic Therapy.Significant improvement was seen at 3 months in the group treated with SRP and photodynamic therapy implying a reduction in bacterial load and gingival inflammation in PDT treated groups.

On intragroup comparison in Group A, the changes in PPD overtime were not statistically significant, indicating minimal improvement. Conversely, Group B showed higher significant reduction in PPD at all time points reflecting better periodontal treatment outcomes.

On intergroup comparison, at baseline Group B had higher PPD than Group A. However, by 1 month and 3 months Group B showed significantly lower PPD, demonstrating more effective periodontal pocket reduction.

Similarly, in clinical attachment level, on intragroup comparison, both groups showed improvement in CAL over time. However, the improvement was not statistically significant in Group A, whereas, Group B exhibited highly significant reduction at all time points.

On intergroup comparison, similar to PPD, Group B demonstrated significantly better CAL gain than Group A at both 1 month and 3 months, indicating more substantial attachment gain and better periodontal regeneration.

These results are in accordance to the studies by **Chowdhury et al (2024)[2]**, in which there was a significant reduction in the probing pocket depth and considerable gain in clinical attachment level at the end of 3 months in photodynamic therapy group.

Antimicrobial photodynamic therapy has several potential advantages like it is minimally invasive therapeutic method. aPDT shows great potential in the treatment of periodontitis, because many oral species were reported to be killed in vitro by this approach making it a promising adjunct to conventional periodontal treatment. It decontaminates the pocket environment as it possesses high bactericidal properties. PDT also has been used to eliminate tumor cells.[20] In addition, certain drawbacks are also seen such as risk of thermal damage to hard tissues, infrastructure required and high investment cost for the laser have to weighed along with the benefits. Along with this, time taken for laser procedure is more and the laser equipment should be used carefully to prevent any damage to vision.[6]

5. CONCLUSION

This clinical study evaluated the effect of photodynamic therapy using an 810 nm diode laser and Indocyanine Green as an adjunct to scaling and root planing on periodontal parameters in patients with chronic periodontitis. Within the limitations of the study, the adjunctive aPDT led to a significant reduction in probing pocket depth and improvements in clinical attachment level. The results of this study are expected to further support the role of laser-assisted photodynamic therapy as a safe and effective therapeutic modality to enhance the outcomes of conventional non-surgical periodontal treatment for chronic periodontitis.However, more longitudinal studies with greater sample size are required to further evaluate the effect of Indocyanine Green as an adjunct to SRP for improving periodontal parameters. Also, microbiological sampling would have provided a better insight into the antimicrobial efficacy of indocyanine green.

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