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Comparative evaluation of postoperative pain and tissue response in patients undergoing conventional flap surgeries with or without 940 nm diode laser exposure - A randomized clinical study

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Abstract:

BACKGROUND: Over the past few years, a growing body of evidence has allowed us to ascertain that the initiation of periodontitis stems from the existence of oral microbial biofilm and that this requires definitive treatment. Owing to its exceptional usability, affordability, and antibacterial activity, the "diode laser" (DL) has increasingly become a popular and important tool in a dentist's armamentarium. However, there is a scarcity of scientific evidence on the utility and advantages of using "diode laser" in periodontal flap surgery. The study aimed to determine the efficacy of 940 nm diode laser exposure in combination with conventional periodontal flap surgery for the treatment of chronic periodontitis to evaluate postoperative discomfort and clinical parameters.

MATERIALS AND METHODS: A total of 10 subjects (7 males and 3 females) with generalized chronic periodontitis were recruited and completed the study without any dropouts. For this split-mouth study, 40 sample sites with pocket probing depth (PPD) 5–7 mm post periodontal Phase I therapy were selected. The quadrants were randomly allocated to Groups A, B, C, and D using the fish bowl lottery method. Kirkland flap surgery with laser and modified Widman flap (MWF) with laser were performed in Group A and C, respectively, while Kirkland flap surgery and MWF surgery were performed in Group B and Group D. Clinical parameters including visual analog scale (VAS) score and gingival inflammation were determined at 3rd and 7th day postoperatively while PPD, clinical attachment level (CAL), and sulcus bleeding index (SBI) were recorded at baseline and 6 months following treatment. Wilcoxon signed-rank test and Kruskal–Wallis test were used for intra-group and inter-group comparison of parameters, respectively.

RESULTS: Statistically significant difference was attained with postoperative discomfort in laser-assisted groups on 1st and 3rd day postoperatively ($P < 0.001$). There was no significant difference in the proportion of subjects with gingival inflammation. A statistically significant reduction in mean PPD at 6 months postoperatively was seen among all study groups ($P < 0.05$) but the inter-group difference was not statistically significant. SBI score reduced significantly from baseline to 6 months follow-up among all four groups ($P < 0.05$). However, we did not find the inter-group difference to be statistically non-significant.

CONCLUSION: Diode laser as an adjunct to the surgical procedure can demonstrate appreciable benefits by increasing the CAL and minimizing the postoperative pain and the probing pocket, but such additional effects were not observed with gingival inflammation.

Keywords:

Diode laser, pain assessment, periodontal pocket debridement, periodontitis

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Introduction

The oral microbiota in periodontitis can house hundreds of bacterial strains, with over 700 distinct phylotypes and around 400 bacterial species detected in subgingival plaque.[1,2] However, only a small percentage is linked to disease progression and is deemed etiologically significant.

Periodontal disease is a result of bacteria inhabiting the oral cavity infecting and causing inflammation in the tissue adjacent to the tooth.[3] The principal objective of periodontal treatment is not only to halt the process of the deterioration of tissues but also to aid the regeneration and rejuvenation of the tissues lost as part of the disease.[4] Mechanical debridement is considered an effective treatment approach for periodontal disease.[5] Restricted mechanical access to areas of the oral cavity such as concavities, developmental grooves, and furcations often rendered the total elimination of bacterial deposits and related toxins difficult from the root surfaces using non-surgical mechanical means, thereby necessitating the need for surgical interventions in such cases.[6,7] Deeper periodontal pockets tend to, thus, necessitate flap surgeries which, therein, tend to achieve a superior reduction in pocket size and a gain in attachment.

The primary objective of using the "modified Widman flap" (MWF) surgical procedure to treat periodontal pockets is the improvement of the re-attachment and re-adaptation of the pocket walls.[8] While total mechanical debridement might be considered the "gold standard" in periodontal treatment,[9] it does not realize the objective of removal of micro-organisms in the soft tissue wall of the periodontal pockets. Furthermore, the complete resection of the deteriorated tissues is not feasible. Soft tissue curettage procedures where means like either usage of ultrasonic or usage of chemicals or agents like antimicrobials, antiseptic, anti-inflammatory, or host-modulating agents have been used, have resulted in varying degrees of success when evaluated for enhancing effects on treatment procedures for chronic periodontitis.[10] The predictability of these treatment procedures is uncertain and there is also an increased probability of the development of resistant microbial strains.

Recent innovations in adjunctive treatments have been introduced and one such new promising technological advancement is a treatment called "therapeutic laser treatment" (or "laser biostimulation"). Therapeutic laser treatment is a non-surgical treatment that not only aids the healing of tissues but also reduces the occurrence of inflammation or edema and pain.[11] Mester *et al*.,[12] in their 1971 paper, pioneered the investigation into the utility of therapeutic laser therapy in rats. Unsurprisingly, laser technology has seen a rapid increase in popularity as an adjunct therapy to surgical treatment owing to its benefits in aiding the tissue healing process.

It is hypothesized that laser affects cellular behavior by influencing the "membrane calcium channels" or "mitochondrial respiratory chain," thereby assisting in the process of angiogenesis, growth factor release, and the synthesis of collagen, all of which accelerate the healing process of wounds.[13] The range of wavelength for diode lasers (DLs) (>800 nm and <980 nm) is known to have high absorption in the hemoglobin and other pigments, and is therefore highly effective in specifically targeting the granulation tissues and the pigmented bacteria preferentially.[14]

Even though laser treatments are considered to offer potential advantages such as sterilizing effect, hemostasis, reduced morbidity, and ablation, their regular usage for periodontal disease treatment is considered a controversial topic.

Considering these bets, this study was aimed at evaluating the efficacy of the "diode laser" (940 nm) biomodification as an adjunct to mechanical debridement in conventional flap surgery for the treatment of chronic periodontitis, postoperative discomfort, and clinical parameters. The null hypothesis was that there would be no statistically significant differences between the groups based on the clinical parameters: Visual analog scale (VAS) score, pocket probing depth (PPD), clinical attachment level (CAL), and sulcus bleeding index (SBI).

Materials and Methods

Study design and setting

The present study was a single-blinded, split-mouth randomized clinical research executed from March 2019 to October 2020. All the procedures have been performed as per the ethical guidelines laid down by the Declaration of Helsinki 1975, as revised in 2000.

Study participants and sampling

This clinical study included 10 subjects (7 males and 3 females) with 40 sample sites each, in the age range of 25–55 years. Assuming a significance level (α) of 0.05 and desired power of 80%, we arrive at a sample size of 10 participants (40 sites). Subjects were recruited from the outpatient Department of Periodontology. The inclusion criteria stated subjects with good systemic health, had PPD between 5 and 7 mm, had not consumed antibiotics in the preceding 6 months since their initial examination or had not needed any antibiotic premedication for the

treatment of any systemic condition, subjects who had not undergone any periodontal therapy in preceding 6 months, and all the posterior teeth present. Subjects were excluded in case of pregnant or lactating women, those with substance abuse as well as a history of drug allergy, presence of intra-bony defects, and teeth with grade II or III mobility. The study was briefed to all the subjects who enrolled and written informed consent was obtained from them for their willingness to participate in the study [Figure 1]. A comprehensive medical and dental history was recorded which was maintained throughout the study period. Subjects were advised for hematological investigations which included clotting time (CT), bleeding time (BT), hemoglobin percentage (Hb%), random blood glucose level (RBS), and hepatitis B surface antigen (HbsAg) followed by Phase I therapy [Figure 1].

Ethical consideration

Ethical clearance for the study was obtained from the Institutional Ethical Committee of Kalinga Institute of Medical Sciences (KIMS-KIIT University). The ethical approval number - KIMS/KIIT/IEC/181/2018 (Date: 28.09.2018). The data were fully anonymized before the final analysis and confidentiality was maintained.

Data collection tool and technique

Initial therapy (Presurgical assessments)

Full mouth scaling and root planing was performed. Oral hygiene instructions were given and subjects were advised to use 10 ml 0.2% chlorhexidine gluconate mouthwash twice daily for 14 days. At the end of 4 weeks, subjects were revaluated and if they qualified for entry to the study, then a baseline examination was carried out which included the recording of the following parameters.

Measurement of clinical parameters

Irreversible hydrocolloid material was used to make an impression and then study models were prepared. Customized acrylic stent using pink polymerizing resin was fabricated for each patient at the surgical site [Figure 2]. Grooves were prepared in the stents at the site of maximum probing depth in an occluso-apical direction.[15] PPD and CAL were then recorded by using William's graduated periodontal probe- Hu-Friedy USA [Figure 3]. Stents were prepared to standardize probing angulations and reproducible clinical measurements at each of the test and control sites during each examination time – baseline and 6 months postoperatively.

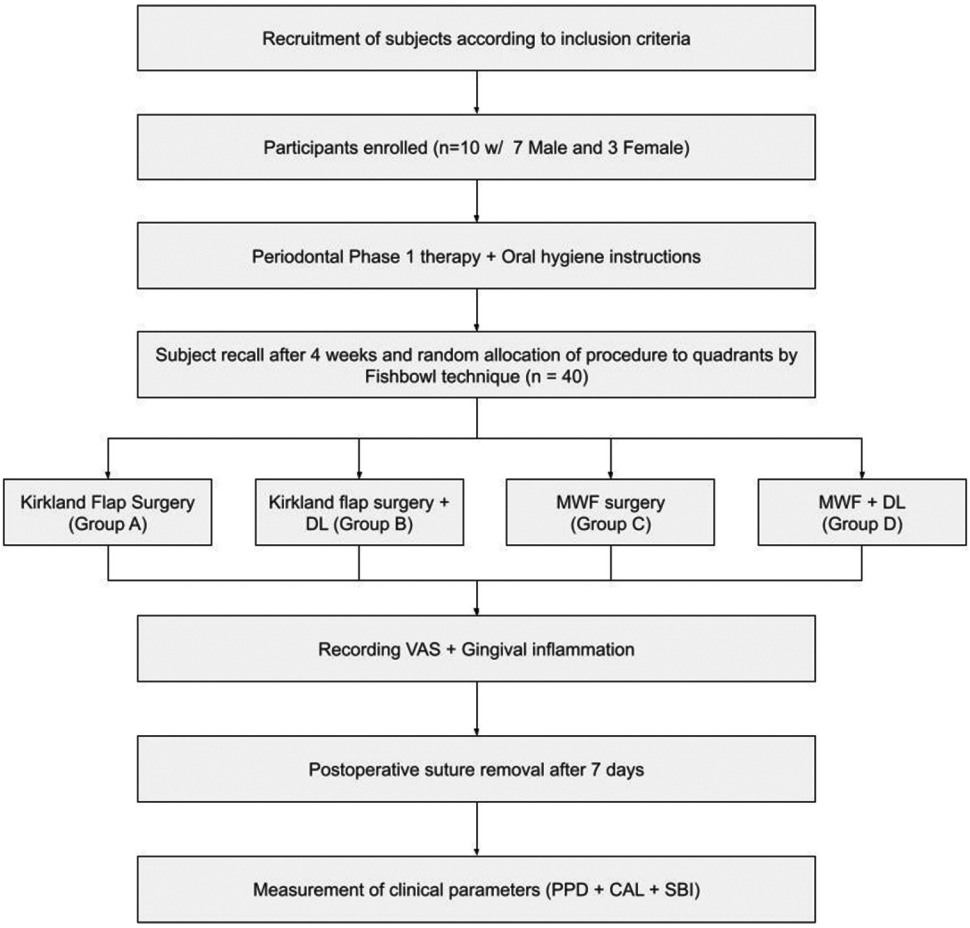

Figure 1: Structural outline of the study

Surgical procedure

Intra-oral and extraoral asepsis were achieved with povidone-iodine solution before administration of local anesthetic solution (2% lignocaine hydrochloride with 1:2,00,000 adrenaline) to the subjects and all the subjective symptoms were evaluated for anesthesia. They were divided into four equal groups [Table 1].

Kirkland flap surgery[16]

In Group A and B, Kirkland flap surgery was first performed. Crevicular incisions were placed within the respective quadrant, which aimed at preserving as much as interproximal tissue as possible. Full thickness mucoperiosteal flaps were reflected and after debridement, surgical areas were irrigated with betadine [Figure 4a, 4b]. Care was taken to keep the site isolated. Flaps were approximated with an interrupted 3-0 black braided silk suture in all the subjects and complete hemostasis was achieved.

Along with the Kirkland flap surgery, in Group A, an arsenide, indium, and gallium diode laser Epic X- BIOLASE California, USA [Table 2] possessing a wavelength of 940 ± 10 nm and a power of 1.5 watt was irradiated on the inner surface of the flap, exposed bone, and exposed root structures involved in a continuous non-contact mode for 30 s before flap closure.

Modified Widman flap surgery[6]

For Group C and D, starting at the gingival margin, 1 mm away from the alveolar crest, the initial incision was made to the alveolar crest on the respective quadrant With the goal of maximizing the preservation of interproximal tissue, sulcular incisions were made from the apical aspect of the pocket to the alveolar bone. After the flap reflection, a third incision was made in the interdental spaces coronal to the bone and the gingival collar was removed. Thorough debridement and root planing were performed; the surgical site was irrigated with betadine [Figure 4c, 4d]. The flaps were approximated with an interrupted 3-0 black braided silk suture in all subjects and complete hemostasis was achieved.

Along with the MWF surgery in Group C, an indium, gallium, and arsenide DL (Epic X Biolase) with a wavelength of 940 ± 10 nm and a power of 1.5 watt was irradiated on the inner surface of the flap, exposed bone, and exposed root structures involved in a continuous non-contact mode for 30 s before flap closure [Figures 5 and 6].

Table 1: Study group distribution

Group distribution	Procedure performed
Group A	Subjects were treated by Kirkland flap with diode laser exposure
Group B	Subjects were treated by Kirkland flap without diode laser exposure
Group C	Subjects were treated with MWF with diode laser exposure
Group D	Subjects were treated with MWF without diode laser exposure

Table 2: Detailed specifications of the laser treatment parameters

Laser composition	Indium, gallium, and arsenide
Power used	1.5 watt
Mode	Continuous non-contact
Duration	30 s each area
Total dose	4 J/cm^2

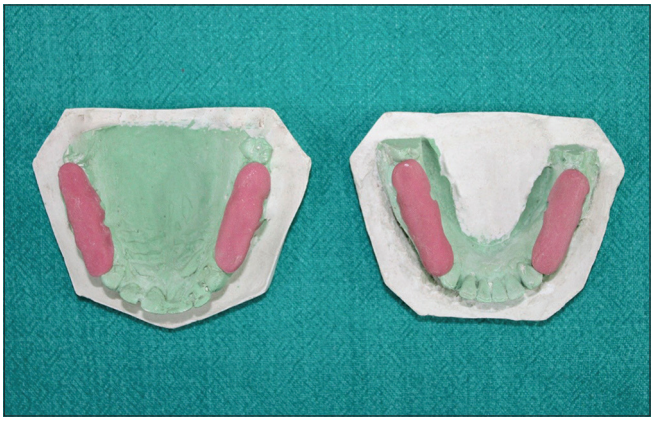

Figure 2: Customized acrylic stents prepared for respective quadrants

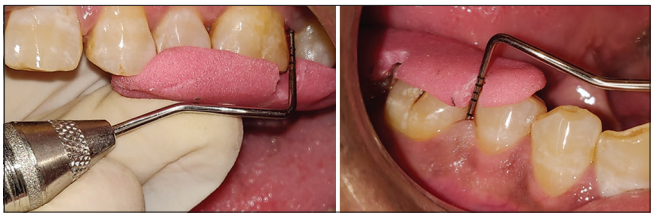

Figure 3: Measurement of preoperative probing depth, clinical attachment level at baseline in the respective quadrants

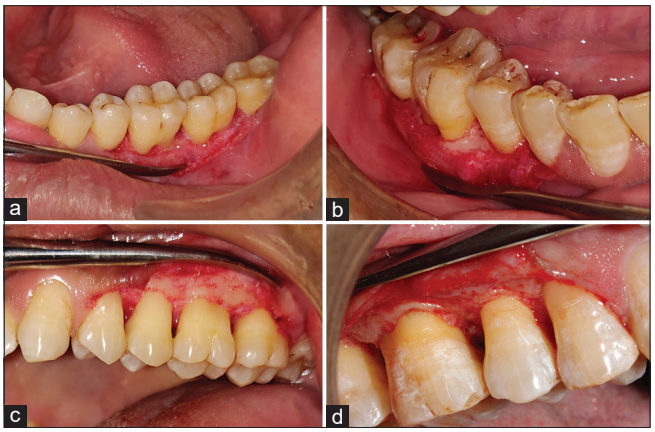

Figure 4: (a) Full thickness flap reflected and complete debridement done irt 34-36. Group A. (b) Full thickness flap reflected and complete debridement done irt 44-47 Group B. (c) Full thickness flap reflected and complete debridement done irt 24-27 Group C. (d) Full thickness flap reflected and complete debridement done irt 14-17 Group D

Only the subjects in groups A and C were treated with DL irradiation before flap closure [Figure 5]. The surgeries were separated by a period of one week. The periodontal dressing was not used in any of the patients, to analyze the gingival inflammation after the 3rd and 7th day, respectively.

Postoperative protocol

All essential postoperative instructions were elucidated to the subjects and they were asked to refrain from brushing at the surgical site for a week. Systemic antibiotic (amoxicillin 500 mg and clavulanic acid 125 mg) twice daily for 3 days and analgesics (aceclofenac 100 mg with paracetamol 325 mg) twice daily for 3 days was prescribed to the subjects. Additionally, they were advised to rinse with lukewarm saline water for a week. Recall visits were fixed on the 1st and 3rd day to evaluate postoperative pain which was recorded using the VAS with 1 indicating least pain whereas 10 meaning extreme pain. Gingival inflammation was analyzed using the gingival inflammatory index for frail elders on the 3rd as well as 7th day. At the end of the 7th day, sutures were removed followed by betadine irrigation. For evaluation of PPD, CAL, and sulcus bleeding, subjects were recalled after 6 months [Figure 7].

Statistical analysis

All the clinical measurements were collected and subjected to statistical analysis using SPSS software version 22 (IBM, Chicago, U.S.A.) in Windows 2010 ASUS E402S Series. When comparing parameter outcomes, the "Wilcoxon signed-rank test" was used for intra-group comparisons, and the "Kruskal Wallis test" was used for inter-group comparisons.

The mean and standard deviation and standard error of all the parameters were calculated.

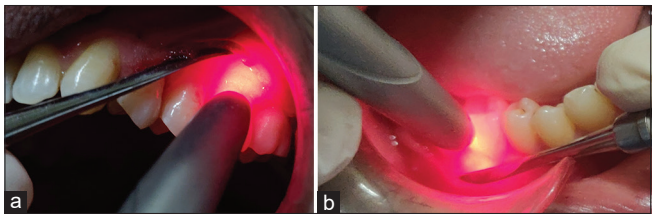

Figure 5: 940 nm a) Diode Laser bio-modification in group A b) Diode Laser bio-modification in group B

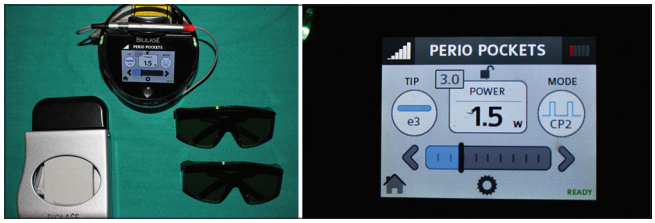

Figure 6: Laser equipment and settings used for application

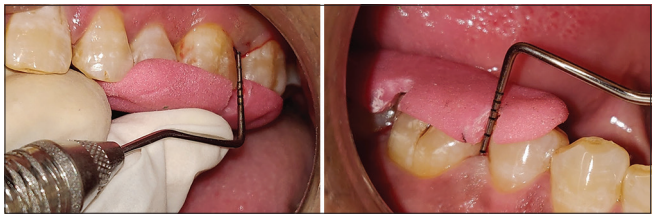

Figure 7: Measurement of postoperative probing depth, clinical attachment level at baseline in the respective quadrants at 6 month

Results

In the present study, we have revaluated the clinical parameters (PPD, CAL, SBI, VAS, and gingival inflammatory index) in treating chronic periodontitis patients. The rationale for integrating regenerative protocol or the application of laser in the overall treatment concept is supported by findings from other clinical and comparative studies. All the 10 enrolled patients (40 sites in total) attended the baseline examination, the treatment session, and the follow-up appointments.

SD = Standard Deviation.

We observed no significant differences between the groups at the baseline examination. Of the 10 individuals who participated in the study, the age of the subjects ranged between 25 and 50 years, with a mean age of 34.90 + 6.38 [Table 3].

We observed a statistically significant reduction in the mean VAS score for postoperative pain among all study groups ($P < 0.05$) [Table 4]. The group with MWF without laser showed the largest reduction in mean VAS score (2.5) followed by MWF with laser (1.7), Kirkland without laser (1.7), and Kirkland with laser (1.4) groups. When comparing inter-group, we also observed a statistically significant difference in VAS score for pain on both day 1 ($P < 0.001$) and day 3 ($P < 0.001$).

On 1st day postoperatively, the mean VAS score was found to be highest in MWF without Laser group (4.40 + 0.84) followed by Kirkland without laser group (2.90 + 0.74), MWF with laser (2.10 + 0.74), and Kirkland with laser group (1.60 + 0.96). However, on 1st day, among all groups, the only significant difference in mean VAS was observed in MWF without laser group with Kirkland with laser group ($P = 0.000$) and MWF with laser group ($P = 0.001$) [Table 4a].

In spite of the highest pain reduction after 3 days in MWF without laser group, the mean VAS score was

Table 3: Distribution of demographic variable

Sex	*n* (%)	Age (Mean+SD)
Male	7 (70)	36.28+6.60
Female	3 (30)	31.66+5.50
Total	10 (100)	34.90+6.38

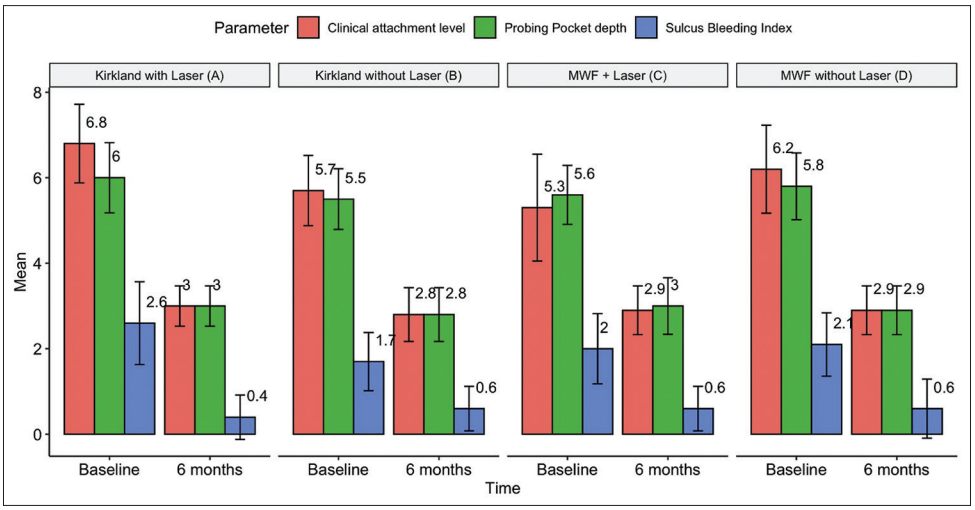

Figure 8: Graph shows how all clinical parameters sulcus bleeding index, clinical attachment level, and PPD changed among groups between baseline and 6-month postoperative evaluation

Table 4: Comparative assessment of postoperative pain at 1st and 3rd day among study groups

Groups	Mean VAS score			*P*@
	1st day (Mean+SD)	3rd day (Mean+SD)	1st day-3rd day (Mean difference)	
Kirkland with Laser (A)	1.60+0.96	0.20+0.42	1.40	0.006*
Kirkland without Laser (B)	2.90+0.74	1.20+0.63	1.70	0.004*
MWF with Laser (C)	2.10+0.74	0.40+0.52	1.70	0.004*
MWF without Laser (D)	4.40+0.84	1.90+0.57	2.50	0.004*
P#	0.000*	0.000*	-	

Test applied: @Wilcoxon Sign rank test, #Kruskal-Wallis test with post hoc, SD=Standard Deviation, VAS=Visual Analog scale, *indicates statistically significant difference

Table 4a: Inter-group comparisons (*post hoc*) *indicates a statistically significant difference

Groups	VAS score mean difference			
	1st day	*P*	3rd day	*P*
A-B	-1.30	0.083	-1.00	0.032*
A-C	-0.5	1.000	-0.20	1.000
A-D	-2.80	0.000*	-1.70	0.000*
B-C	0.80	0.818	0.80	0.167
B-D	-1.50	0.156	-0.70	0.628
C-D	-2.30	0.001*	-1.50	0.001*

highest (1.90 + 0.57) followed by Kirkland without laser group (1.20 + 0.63), MWF with laser (0.40 + 0.52), and Kirkland with laser group (0.20 + 0.42) [Table 4].

However, on the 3rd day, among all groups, the mean VAS score is significantly different between Kirkland with laser group and Kirkland without laser group ($P = 0.032$); Kirkland with laser group and MWF without laser group ($P = 0.000$) and between MWF with laser and without laser groups ($P = 0.001$) [Table 4a].

Table 5 shows the gingival bleeding status at baseline and 6 months among study groups. The mean SBI score reduced significantly from baseline to 6-month follow-up among all four groups ($P < 0.05$). The highest reduction in bleeding was observed in Kirkland with laser group (2.20) followed by MWF without laser (1.50), MWF with laser (1.40), and Kirkland without laser (1.10) group. The mean SBI score at baseline was maximum among Kirkland with laser group (2.60 + 0.97) followed by MWF without laser (2.10 + 0.74), MWF with laser (2.00 + 0.82), and Kirkland without laser group (1.70 + 0.68). However, we find that the difference between groups was statistically non-significant ($P = 0.161$). After 6 months postoperatively, the mean SBI score did not vary significantly ($P = 0.807$) and was more or less similar in values.

Table 6 shows a statistically significant decrease in the mean PPD 6 months postoperatively among all study groups ($P < 0.05$) with the highest reduction being depicted by Kirkland with laser group (3.00) followed by MWF without laser (2.90), Kirkland without laser (2.70), and MWF with laser group (2.60). At baseline, the mean PPD was maximum among Kirkland with laser group (6.00 + 0.82) followed by MWF without laser (5.80 + 0.78), MWF with laser (5.60 + 0.69), and lowest among Kirkland without laser group (5.50 + 0.71). However, we find no statistically significant difference between the groups ($P = 0.467$). At 6 months follow-up, Kirkland with laser (3.00 + 0.47) group and MWF with laser (3.00 + 0.66) groups displayed similar mean probing depth with slight variation from MWF without laser (2.90 + 0.57) and Kirkland without laser (2.80 + 0.63) groups. We find no statistically significant difference between the groups ($P = 0.835$).

Table 7 shows a statistically significant reduction in mean CAL after 6 months postoperatively among all study groups ($P < 0.05$). The highest reduction in CAL was observed in Kirkland with laser group (3.8) followed by MWF without laser (3.3), Kirkland without laser (2.9), and MWF with laser (2.4) groups. At baseline, mean CAL was found to be highest in Kirkland with laser group (6.80 + 0.92) followed by MWF without laser (6.20 + 1.03), Kirkland without laser (5.70 + 0.82), and MWF with laser (5.30 + 1.25) groups, a difference we found to be statistically significant in a Kruskal–Wallis test ($P = 0.024$). Upon further analysis, we find that at baseline, among all groups, the only significant difference in mean CAL was observed in Kirkland with laser group and MWF with laser group ($P = 0.027$).

At 6 months follow-up, the mean CAL did not vary significantly ($P = 0.866$) with almost similar mean values among all groups [Table 7a].

A higher proportion of subjects showed gingival inflammation on the 3rd day postoperatively which reduced subsequently on the 7th day among all groups but the difference was statistically non-significant ($P > 0.05$). There was no significant difference in the proportion of subjects with gingival inflammation on the 3rd day ($P = 0.244$) and 7th day ($P = 0.190$) according to study groups [Table 8]. Overall Graph showing the clinical parameters at baseline and 6 month time interval [Figure 8].

Discussion

The ultimate objective of periodontal therapy is focused on disease prevention, halting the progression of the disease by suppressing pathogenic organisms, regeneration of lost periodontal tissues as well as preserving and prolonging the therapeutic goals.[17] The utility of lasers along with mechanical debridement has been a contentious topic with multiple systemic reviews indicating that lasers provide negligible to no additional advantage. Therefore, the present investigation was intended to determine the efficacy of 940 nm diode laser exposure in combination with conventional flap surgery for the treatment of chronic periodontitis based on postoperative pain and clinical parameters. Based on the type of tissue at which the laser is directed and the wavelength of the laser, different lasers exhibit varied depths in the tissue, resulting in a wide range of applications. Compared to conventional mechanical methods, the 940 nm diode laser shows a guided tissue regeneration-like effect – therefore beneficial in aiding epithelial migration and achieving a more complete

Table 5: Comparative assessment of gingival bleeding status at baseline and 6 months among study groups

Groups	Sulcus bleeding index score			*P*@
	Baseline (Mean+SD)	6 months (Mean+SD)	Baseline-6 months (Mean difference)	
Kirkland with Laser (A)	2.60+0.97	0.40+0.52	2.20	0.005*
Kirkland without Laser (B)	1.70+0.68	0.60+0.52	1.10	0.009*
MWF with Laser (C)	2.00+0.82	0.60+0.52	1.40	0.004*
MWF without Laser (D)	2.10+0.74	0.60+0.69	1.50	0.004*
P#	0.161	0.807		

Test applied: @Wilcoxon Sign rank test, #Kruskal-Wallis test with *post hoc*, SD=Standard Deviation, *indicates statistically significant difference

Table 6: Comparative assessment of PPD at baseline and 6 months among study groups

Groups	PPD			*P*@
	Baseline (Mean+SD)	6 months (Mean+SD)	Baseline-6 months (Mean difference)	
Kirkland with Laser (A)	6.00+0.82	3.00+0.47	3.00	0.005*
Kirkland without Laser (B)	5.50+0.71	2.80+0.63	2.70	0.004*
MWF with Laser (C)	5.60+0.69	3.00+0.66	2.60	0.004*
MWF without Laser (D)	5.80+0.78	2.90+0.57	2.90	0.004*
P#	0.467	0.835	0.613	

Test applied: @Wilcoxon Sign rank test, #Kruskal Wallis test, SD=Standard Deviation, *indicates statistically significant difference

Table 7: Comparative assessment of clinical attachment level at baseline and 6 months among study groups

Groups	Clinical attachment level			*P*@
	Baseline (Mean+SD)	6 months (Mean+SD)	Baseline-6 months (mean difference)	
Kirkland with Laser (A)	6.80+0.92	3.00+0.47	3.80+0.92	0.004*
Kirkland without Laser (B)	5.70+0.82	2.80+0.63	2.90+1.37	0.005*
MWF with Laser (C)	5.30+1.25	2.90+0.57	2.40+1.43	0.007*
MWF without Laser (D)	6.20+1.03	2.90+0.57	3.30+0.95	0.005*
P#	0.024*	0.866		

Test applied: @Wilcoxon Sign rank test, #Kruskal-Wallis test with *Post Hoc*, SD=Standard Deviation, *indicates statistically significant difference

Table 7a: Intergroup comparisons (*Post hoc*) *indicates statistically significant difference

Groups	Clinical attachment level mean difference	
	Baseline	*P*
A-B	1.10	0.026*
A-C	1.50	0.027*
A-D	0.60	1.000
B-C	0.40	1.000
B-D	-0.50	1.000
C-D	-0.90	0.695

Table 8: Comparative assessment of gingival inflammation at 3rd day and 7th day among study groups

Groups	Gingival inflammation *n* (%)		*P*@
	3rd day	7th day	
Kirkland with Laser (A)	4 (40)	1 (10)	0.25
Kirkland without Laser (B)	7 (70)	5 (50)	0.625
MWF with Laser (C)	5 (50)	2 (20)	0.25
MWF without Laser (D)	8 (80)	4 (40)	0.125
P#	0.244	0.190	

Test applied: @Mc Nemar test, #Chi square test

removal of the epithelium.[18] DL comparatively possesses an exceptionally high absorption rate by hemoglobin and other pigments, thereby allowing it to selectively target the anaerobic bacteria and granulation tissue at a wavelength range between 800 and 980 nm. The superiority of DL lies in its ability for the coagulation of tissue by heat-producing high-frequency wavelength and electric current providing an immediate hemostatic effect leading to the formation of a charred layer. Moreover, DL being bactericidal in action also aids in efficient sulcular debridement and soft tissue curettage with no detrimental effect on the dental hard tissue.[19]

In this study, we evaluated the clinical parameters such as PPD, CAL, bleeding, and effectiveness of DL on postoperative pain and gingival inflammation. The application of DL along with periodontal surgery did not cause any postoperative complications or adverse reactions in gingival inflammation, suggesting that this type of laser has no negative consequences. The fundamental purpose of our study is to employ a pain scale that is subjective in nature and entirely dependent on every individual's perception of pain. Moreover, the split-mouth concept was incorporated intending to reduce the bias. The subjective measure of the pain using the VAS found statistically significant differences between the laser sites versus non-laser sites at the end of 6 months. The region irradiated with laser had lesser postoperative discomfort as reported by the subjects. This can be attributed to the fact that by slowing down the conduction velocity (CV) and decreasing the amplitude of compound action potentials, the laser causes an inhibitory impact on peripheral neurons.[20] Moreover, the laser seals the sensory nerve endings and inhibits pain receptors such as bradykinin. It normalizes ion channels [cellular gatekeepers] and releases endorphins and enkephalins that produce an analgesic effect.[20] The findings of our study were similar to the pilot research conducted by Ravi *et al*.[21] who evaluated the effect of biostimulation with 980 nm laser in pain and tissue response following periodontal therapy where the mean pain response declined on the third day for Kirkland flap surgery with and without DL biostimulation, respectively, concluding that the use of DL had a considerable impact on immediate postoperative pain, minimizing the requirement for analgesics. In addition to that, a recent investigation by Khan *et al*.[22] stated that the adjunctive biostimulant effect of the DL resulted in the decrease of postoperative pain in the laser group. A similar outcome was reported in a landmark study by Sanz moliner *et al*.[23] where the author utilized a DL with 810 nm with MWF surgery and they achieved a statistically significant difference in pain scale assessment favoring the laser group. This signifies that the laser might be more advantageous in cases where the patient or the physician anticipates post-surgical pain. The results of Nagaraj *et al*.[24] revealed that postsurgical pain and tissue edema could be minimized when the DL is used, but without considering the treatment schedule and the optimal dosage, it might be hard to assess its efficacy.

In the present study, a higher proportion of subjects showed gingival inflammation on the 3rd day postoperatively which reduced subsequently on the 7th day among all groups but the difference was statistically non-significant. This finding correlates with the study conducted by Ravi *et al*.[21] who found no clinical and statistical difference in reduction of gingival inflammation using 980 nm DL. Low-level laser light dosimetry is crucial to the effectiveness of infra-surgical treatments. This follows from the "Arndt Schultz law" that states "small doses stimulate, medium doses impede and large doses destroy living systems."[25] By using lasers, ATP (adenosine triphosphate), or stored energy, is increased. The main rationale to keep CAL as one continuous measurable variable stems from the fact that it is considered the most accurate clinical parameter for the determination of periodontal stability.[26] In the current investigation, CAL reveals a statistically significant reduction in mean attachment level following 6 months postoperatively among all study groups. The highest reduction in CAL was depicted in Kirkland with laser group followed by MWF with laser, and least in Kirkland without laser and MWF without laser groups. Compared to the non-laser group, the laser group exhibit a greater gain in CAL from the 0th day to the 3rd and 6th months, however, this difference was not found to be of statistical significance. The results of our study correlate with the clinical investigation by Shetty *et al*.[27]

who observed that at all time intervals throughout the course of the research, both the test and control groups improved in terms of relative attachment level. The difference between the two groups, however, was not found to be statistically significant. We find that our results correlated well with those observed by Aena *et al*.,[28] in that the laser-assisted Kirkland flap group yielded better outcomes than the Kirkland flap group at the end of 6 months.

PPD showed a significant reduction in mean PPD 6 months postoperatively among all study groups with the highest reduction being depicted by Kirkland with laser group, followed by MWF with laser as compared to Kirkland without laser and MWF without laser. At baseline, the mean PPD at baseline was maximum among Kirkland with laser Group. However, we observed that the inter group difference was statistically non-significant in our study. This finding correlates with an analogous study carried out by Lobo and Pol[29] where the baseline mean probing depth in the open flap debridement (OFD) + laser group was considerably reduced at 6 months when compared to OFD, although the results were statistically insignificant among the groups. In another analysis, Kartikeyan *et al.* conducted an inter-group comparison of mean values of PPD between control and test groups. We observed a statistically significant reduction in PPD in the test group, from the 0th day to the 3rd and 6th month, compared to the control group. The higher level of anti-inflammatory cytokines and enhanced microcirculation caused by laser irradiation accounts for the increased reduction in the PPD of the laser-treated group. In the present study, the "mean sulcus bleeding index" score reduced significantly from baseline to 6 months follow-up among all four groups. The highest reduction in bleeding was observed in Kirkland with the laser group. However, we found the inter-group differences to be not statistically significant. After 6 months postoperatively, the mean SBI score did not vary significantly and was more or less similar in values. Karthikeyan *et al*.[30] in their study showed that while there was a mean reduction in bleeding at the 6th-month mark in both the control and the treatment group, the subjects in the test group exhibited an even more statistically significant reduction in bleeding when compared with those in the control group at the 3rd- and 6th-month mark. Furthermore, while all the four procedures used enhanced the clinical outcomes, the use of "diode laser" as an adjunct to Kirkland and MWF surgery resulted in a more statistically significant improvement in bleeding on probing, postoperative pain, and PPD. The physical repercussion of laser therapy is the risk of retinal or corneal burn. Therefore, the nominal hazard distance which is up to a few meters[31] must be maintained throughout and the possibility of ocular damage should be taken into consideration, especially when using an invisible and collimated (parallel) beam. Therefore, both the operator and the subject must take account of the safety precautions and wear appropriate protective eyewear. There is almost no possibility of malignant alterations occurring because the therapeutic lasers are much above the ionizing range. Certain limitations regarding the study such as lack of standardization of the amount of laser energy delivered could have influenced the observations. A greater sample size, double blinding, and inclusion of other clinical indices and longitudinal studies, are warranted to further authenticate the results of the present study.

Conclusion

The healing process was found to be uneventful in all four groups and no major complications were reported by the subjects. Due to its reasonable price, good tissue penetration, opportune to use, and compact structure, DL is being widely employed by dental practitioners and institutions. Therefore, based on our findings, we conclude that implementing DL as a supplement to surgical debridement provided appreciable benefits enhancing the treatment outcome on the whole.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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