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Effect of Galium Arsenide Diode Laser on Human Periodontal Disease: A Microbiological and Clinical Study

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Background and Objective: The present study is aimed to describe short-term results on selected microbiological and clinical parameters obtained by treatment with soft laser in conjunction with methylene blue and/or mechan- ical subgingival debridement in human periodontal disease.

Study Design/Materials and Methods: Ten patients, in whom each dental quadrant was randomly designated to receive one of four types of treatment procedures, were included in the study. Groups of quadrants received: scaling/root planing (SRP); laser application (L); SRP combined with L (SRP/L); oral hygiene instructions (OHI). Four single rooted teeth (one in each quadrant), having an interproximal site with a probing depth of 4 mm mesio-buccally, were selected in each patient. The selected teeth were ®rst assessed for microbiological (one site/tooth) and then for clinical variables (six sites/tooth). Supragingival irrigation with methylene blue was performed prior to laser application. The microbiological (proportions of obligate anaerobes) and clinical measurements (plaque and gingival indices, bleeding on probing, probing pocket depth) were evaluated over a period of 32 days.

Results: Only the SRP/L and SRP groups provided signi®cant reductions in the proportions of obligate anaerobes before and after treatments with no signi®cant differences in between. Parallel to the microbiological changes, both SRP/L and SRP resulted in similar clinical improvements, whereas L alone revealed a limited effect similar to OHI.

Conclusion: Within the limits of this study, methylene blue/soft laser therapy provided no additional microbiological and clinical bene®ts over conventional mechanical debridement. Lasers Surg. Med. 30:60±66, 2002.

Key words: anaerob micro-organisms; mechanical periodontal therapy; soft laser

INTRODUCTION

Successful periodontal treatment is dependent on the stoppage of tissue destruction, elimination or control of etiological agents together with a microbial shift toward one typically present in health [1,2]. The elimination of the pathogenic subgingival microbiota may be achieved by non-surgical scaling and root-planing [3±5]. However, mechanical therapy alone, may fail to eliminate the pathogenic bacteria because of their location within the gingival and dental tissues or in other areas inaccessible to periodontal instruments [6,7]. These limitations and the improved biological understanding of periodontal diseases together with the emerging evidence of bacterial speci-®city have led to a move in emphasis from a pure mechanical approach to other methods which include the use of adjunctive antimicrobial measures. Methods of killing periodontal pathogens, therefore, are of great interest and considerable attention has been devoted to the possibility of using antibiotics or antiseptics in this respect. More recently, it has been suggested that high-power lasers, such as Nd/YAG laser, which emit light in the infrared region may be useful for destroying such organisms, presumably by a thermal effect [8]. However, the clinical use of such high-power lasers introduces problems from the point of view thermal side effects on surrounding tissues [9]. An alternative approach using light in the visible region of the electromagnetic spectrum would be more attractive from the point of view of safety. Although most species of oral bacteria do not absorb visible light and so are largely unaffected by such radiation, assimilation or adsorbtion of a colored compound by these organisms can sensitize them to visible light [10]. It has been shown in in vitro studies that it is possible to kill oral bacteria with light from a low power laser, once they have been sensitized by various dyes such as toluidine blue O or methylene blue [10±16]. This implies that low power lasers, in conjunction with appropriate photosensitizers, may be a useful adjunct to mechanical debridement in the treatment of in¯ammatory periodontal diseases if a similar effectiveness can be achieved in vivo. To the best of our knowledge, no investigations evaluating the use of low power soft lasers in conjunction with topically applied photosensitizers in the treatment of periodontal diseases are available in the literature. Therefore, the purpose of this study was to examine the short-term effect of low power

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soft laser therapy in conjunction with topical methylene blue and/or mechanical subgingival debridement on periodontal pockets with regard to the antimicrobial abilities and the improvement of periodontal condition.

MATERIALS AND METHODS

The study group comprised ten systemically healthy subjects with early to mild periodontitis who applied for treatment to the clinics of the Department of Periodontology at the Faculty of Dentistry, Marmara University and Yeditepe University. Patients who have taken antibiotics or received periodontal treatment within 6 months preceding the study were not included. They were instructed about the nature and purpose of the study and consents were obtained. Prior to any treatment procedure, oral hygiene instructions (OHI) were given. Each quadrant of the subjects was randomly assigned to one of the following groups: scaling and root planning combined with laser application (SRP/L), laser application (L) alone, scaling and root planning (SRP) alone, and OHI alone. Patients were asked to rinse with methylene blue (Buco bleu 15 g, Koz Ilac San. Ve Tic. A.S.) for 1 minutes prior to laser application. Solutions were made up on a w/v basis (0.005%) [11].

Site Selection

Four single-rooted teeth (one in each quadrant) having an approximal site with a probing depth of 4 mm mesio-buccally were selected in each patient. To enhance the accuracy of measurement and simplify microbial sampling, mesio-buccal sites were chosen. The selected teeth were ®rst assessed for microbiological (one site/tooth) and then for clinical variables (six sites/tooth). Clinical measurements were performed by a single examiner, whereas microbial culturing was done by another individual.

Microbiological Procedures

After super®cial cleaning of the sites with cotton pellets and drying of the supragingival area with a stream of air, samples were taken by sterile paper points inserted into the depth of the pocket, left for 10 seconds and cultured as described by Noyan et al. [17] and Kuru et al. [18]. Brie¯y, each sample was aseptically transferred to 4.5 ml of phosphate buffered saline (PBS) and immediately dispersed using a vortex mixer at maximal setting for 60 seconds. The dispersed samples were serially diluted, and 0.2 ml portion of 10^{-1}, 10^{-2},. . .,10^{-5} dilutions were spread on a solid agar medium using sterile bent glass rods.

Trypticase soy agar plate (Oxoid Ltd.; Hamsphire, England) enriched with 0.0005% hemin (Sigma Chemical Co.; St. Louis, MO, USA), 0.00005% menadione (Sigma), and 5% de®brinated sheep blood, was inoculated for non-selective bacterial growth [19]. Furthermore, trypticase soy agar plate enriched with 5% de®brinated sheep blood was used for cultivation for facultative anaerobic micro-organisms.

After 7 days of incubation of the supplemented trypticase soy agar plates in Gas Pak jars (Gas generating kit, Oxoid) in an atmosphere of 95% H_2 and 5% CO_2 at 378C, the total viable count (TVC) was determined from the dilution giving 30±300 colonies. TVC was expressed in terms of milliliter of transport medium. Colonies were identi®ed by the analysis of colony morphology, aerotolerance, pigmentation, Gram staining procedures, motility, catalase and oxidase activity, and using API 20 A strips (BioMerieux, France). After 5 days of incubation of trypticase soy agar plate in air and 10% CO_2 at 378C, the total number of facultative anaerobes was determined.

All the microbiologic data were transformed into colony forming units/milliliter (CFU/ml). Obligate anaerobic bacteria was calculated as the total counts of anaerobically cultivable bacteria (TVC) minus the total counts of facultatively anaerobic bacteria and expressed as a percentage of TVC.

Clinical Parameters

Clinical measurements were performed at the selected teeth that were assessed for microbiological variables. The measurements included plaque index (PI) [20], gingival index (GI) [21], bleeding on probing (BOP), and probing pocket depth (PPD) to the nearest mm using a calibrated manual probe (PQ-OW Chicago, IL, USA, Hu-Friedy Instrument Co.).

Laser

The laser used was a Gallium-Arsenide diode laser (BTL-2000 Prague, Check, Rep., BTL Co., Check Rep.) operating at a frequency of 5.0 Hz and delivering a 30 mW continuous wave output at 685 nm with a power density of 1.6 J/cm^2. Patients received 1.11 minutes treatment three times a week over each papillary region as recommended by the manufacturer. During application, protective eyeglasses were worn both by the operator and the patient.

Study Design

The study design is presented in Table 1. Seven days before commencement of the experimental procedures, oral hygiene instructions were given. The day when microbiological samples and clinical records were taken was designated as the day 0. On the days 1 and 7, the mechanical subgingival debridement was undertaken using the ultrasonic and hand instruments for the SRP/L and SRP groups. This procedure was followed immediately by soft laser application for the SRP/L group as well as the L group. On the days 2, 4, 9, and 11, the soft laser was applied to the SRP/L and L groups. Methylene blue was applied as a mouth rinse prior to laser application. The OHI group received neither mechanical debridement nor laser application. Three weeks after therapy procedures, microbiological samples were obtained and clinical measurements were repeated.

After completion of the experimental period, the quadrants which received laser application alone and OHI alone were subjected to further mechanical subgingival debridement.

Statistics

Differences between the pre- and post-treatment values within each group and differences between the changes of

TABLE 1. Study Design

		Groups			
Procedure	Time (days)	SRP and laser	Laser	SRP	OHI
Oral hygiene instructions	À7	‡	‡	‡	‡
Microbiological sampling	0	‡	‡	‡	‡
Clinical measurements	0	‡	‡	‡	‡
Mechanical debridement	1	‡		‡	
Laser application	1	‡	‡		
Laser application	2	‡	‡		
Laser application	4	‡	‡		
Mechanical debridement	7	‡		‡	
Laser application	7	‡	‡		
Laser application	9	‡	‡		
Laser application	11	‡	‡		
Microbiological sampling	32	‡	‡	‡	‡
Clinical measurements	32	‡	‡	‡	‡

the pre- and post-treatment values among groups were compared using the Wilcoxon matched-pairs signed rank test [22] using the NCSS statistics package program on an IBM compatible computer. The probability value for statistical signi®cance was set at P ` 0.05.

RESULTS

There were no complaints such as discomfort, sensitivity or pain from subjects immediately after laser irradiation as well as 3 weeks post-therapy. The approach of patients appeared to be positive toward laser.

Microbiological Assessments

TVC (total anaerobically grown) and obligate anaerobic micro-organisms (total viable counts of anaerobically cultivable bacteria minus the total counts of facultatively anaerobic bacteria determined using parallel sets of aerobically and anaerobically incubated agar plates) expressed as a percentage of TVC in subgingival samples before and after different treatments, are given in Tables 2 and 3.

Following subgingival mechanical debridement combined with laser application (SRP/L), a decrease in TVC from the mean baseline value of 19.08 Æ 18.62 to 15.31 Æ 20.67 was noted. However, this reduction along with minor ¯uctuations in other groups was not signi®cant (Table 2).

Table 3 demonstrates the differences from baseline in percent obligate anaerobes of TVC in four test groups. The proportions of obligate anaerobes decreased notably in all groups. However, only the SRP/L and SRP groups provided signi®cant changes from baseline to 32 days post-therapy values (from 50.54 Æ 27.29 to 16.36 Æ 22.28, and from 47.66 Æ 26.62 to 16.06 Æ 17.54, respectively) (P ` 0.05). When changes in the proportions of obligate anaerobes between the four groups were compared, as shown in Table 4, the differences between the SRP/L and L, SRP/L and OHI, and SRP and OHI were found to be signi®cant (P ` 0.05).

Clinical Assessments

Improvements with respect to clinical parameters occurred in all groups between the baseline and post-therapy measurements. The analysis of the PI (Fig. 1) and GI (Fig. 2) parameters indicated signi®cant reductions from baseline to day 32 for all groups (P ` 0.05). With respect to the BOP, signi®cant reductions were observed in the SRP/L and SRP groups (P ` 0.05), whereas the reductions in this parameter of the L and OHI groups were found insigni®cant (Fig. 3). Similarly, PPD declined signi®cantly in the SRP/L and SRP groups after treatment

TABLE 2. Total Viable Counts (Â 10^3 CFU/ml) of Subgingival Samples at the Baseline and 3 Weeks After Treatment

	SRP and laser	Laser	SRP	OHI
Baseline	19.08 (Æ 18.62)	15.69 (Æ 8.92)	10.57 (Æ 7.19)	12.60 (Æ 8.32)
Post-therapy	15.31 (Æ 20.67)	15.89 (Æ 9.40)	8.41 (Æ 7.40)	11.04 (Æ 8.36)
Z	1.27	0.05	0.56	0.36
P	0.20^{NS}	0.96^{NS}	0.58^{NS}	0.72^{NS}

Data are presented as the mean values and the numbers in brackets are the standard deviations.

SRP, scaling and root planning; OHI, oral hygiene instruction; NS, not signi®cant.

TABLE 3. Proportions of Obligate Anaerobes Expressed as Percentage of Total Viable Counts at the Baseline and 3 Weeks Post-Therapy, and the Change (BaselineÐ3 Weeks)

	Laser and SRP	Laser	SRP	OHI
Baseline	50.54 (Æ 27.29)	52.42 (Æ 23.10)	47.66 (Æ 26.62)	37.19 (Æ 26.41)
Post-therapy	16.36 (Æ 22.28)	41.59 (Æ 24.13)	16.06 (Æ 17.54)	27.04 (Æ 23.18)
Change	34.18* (Æ 29.58)	10.88 (Æ 29.75)	31.59* (Æ 28.35)	10.15 (Æ 18.36)
Intergroup Statistics		T ˆ 8.49	P ˆ 0.037**	

*P ` 0.05, intragroup comparison.

**P ` 0.05, intergroup comparison.

SRP, scaling and root planing; OHI, oral hygiene instruction.

procedures (P ` 0.05), as shown in Figure 4. Although the PPD score also tended to decrease in the L and OHI groups, these reductions were not signi®cant.

Comparisons of the changes in the clinical parameters before and after therapy among the groups are shown in Table 5. Similar changes were observed in the SRP/L and SRP groups and the differences between these two groups in all clinical parameters were not statistically signi®cant. In contrast, the L group demonstrated signi®cantly less reductions in the PI, BOP, and PPD measurements compared to the SRP/L group (P ` 0.05) except the GI parameter. In addition, no signi®cant differences were noted between the L and OHI groups.

Taking the changes in all microbiological and clinical parameters into consideration, the mechanical subgingi- val debridement alone or in combination with laser application was observed to be more effective as compared to laser application alone.

DISCUSSION

Laser technology originated in 1960 and has developed since then. Recently the use of laser therapy has appeared with increasing frequency in the dental literature. It should be emphasized that there are different theories on the effects of laser and still many questions concerning its therapeutic value are unanswered. At the present time, the antimicrobial effects of low power lasers have not been substantiated. In assessing the potential antimicrobial effects of low power laser irradiation, a number of investigations to date has been done. Moritz et al. in their studies suggested that irradiation with the diode laser with a wave length of 805 nm facilitates bacterial elimination from periodontal pockets [23,24]. On the other hand, in vitro studies pointed out that in the absence of an appropriate photosensitizer, exposure to low power laser light had no signi®cant effect on the viability of the pure cultures of suspected periodontal pathogens such as Porphyromonas gingivalis, Actinobacillus actinomycetem- comitans, and Fusobacterium nucleatum [10±12]. It is also reported that oral bacterial species most of which do not absorb visible light and so are unaffected by such irradiation can be killed by red light from a helium/neon laser following sensitization with various dyes, especially toluidine blue O and methylene blue [10±13]. Haas et al. in another in vitro study found that dye/laser treatment resulted in the destruction of bacterial cells on different implant surfaces [14]. In a recent study, Dortbudak et al. evaluated the laser effect on peri-implantitis-associated bacteria in vivo [25]. Although the complete elimination of bacteria was not achieved in this study, authors con®rmed the bactericidal effect of toluidine blue O/laser treatment when the dye applied topically on implant surfaces.

TABLE 4. Intergroup Comparison of the Changes in the Proportions of Obligate Anaerobes Before and After Treatments

	Laser and SRP	Laser	SRP	OHI
Laser and SRP		2*	0.53	2.11*
Laser	2*		1.81	0.38
SRP	0.53	1.81		2.11*
OHI	2.11*	0.38	2.11*	

Data are presented as the z value.

*P ` 0.05.

Given the problems in extrapolating irradiation para- meters and ®ndings from in vitro research to human practice, trials in humans are essential. The use of dye/soft lasers in periodontal treatment in terms of their bacter- icidal effects has not been investigated in vivo. It is observed that higher doses are required to produce in vivo clinical effects than those commonly used for in vitro research [26]. One of the major problems in evaluating the laser ef®cacy is the determination of the optimal dosage and treatment schedule. With low power lasers, this remains an area of controversy both in medicine and dentistry. Although there is some guidance from other experiments, the choices remains discouragingly wide. Furthermore, there are great differences in the published literature in terms of experimental and assessment methods and irradiation conditions. The laser used for therapy in this study was a Gallium±Arsenide diode laser operating at a frequency of 5.0 Hz and delivering a 30 mW continuous wave output at 685 nm with a power density of 1.6 J/cm^2. Patients received 1.11 minutes treatment three times a week over each papillary region as recommended by the manufacturer. In the present well-controlled split- mouth - study providing a comparison by eliminating subject- based differences, topical methylene blue/laser

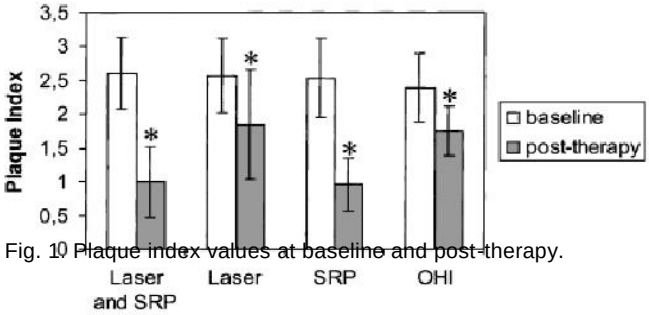

Fig. 1. Plaque index values at baseline and post-therapy.

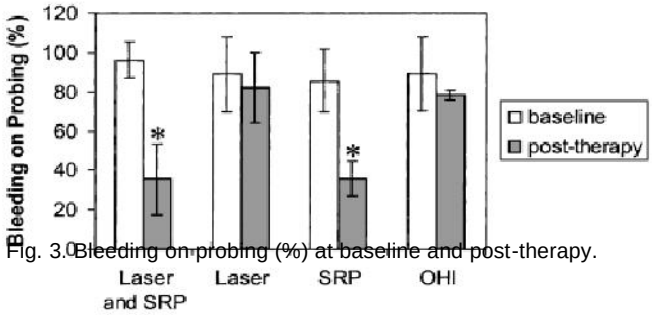

Fig. 3. Bleeding on probing (%) at baseline and post-therapy.

treatment produced no signi®cant antimicrobial effects at the aforementioned settings.

Methylene blue was used as the photosensitizer and applied as a mouth rinse prior to laser irradiation, since it is expected that agents in mouth rinses during supragin- gival irrigation can be projected into pockets less than 5 mm in depth and access to subgingival plaque can be achieved [27,28]. No signi®cant reductions in the propor- tions of subgingival obligate anaerobes were detected before and after laser treatment alone. Within SRP and SRP/L groups, signi®cant reductions in the proportions of obligate anaerobes were observed before and after treat- ments. However, intergroup comparison revealed no signi®cant differences in between the groups SRP and SRP/L.

Clinical results of this study showed improvements when parameters recorded at the baseline and 3 weeks after procedure were compared. All treatment groups showed decreases in the PI, GI, BOP, and PPD para- meters. However, signi®cant reductions in PPD and BOP were observed only in the groups where mechanical subgingival debridement was performed (the SRP/L and SRP groups). This is consistent with the other studies in the related literature con®rming the importance of mechanical debridement as the cornerstone for control and prevention of periodontal disease [1,17,29,30]. On the contrary, laser application without elimination of local aetiological factors resulted in insigni®cant reductions in PPD and BOP similar to oral hygiene regimens [31,32]. Supragingival plaque removal alone is unlikely to be suf®cient to control periodontal diseases as also demon- strated by Listgarten et al. [3] and Beltrami et al. [33]. However, some shrinkage of the gingival tissues with some reduction of in¯ammation may occur [17,32,34]. L and OHI groups seems to have the least favorable clinical results when compared to SRP/L and SRP alone. This may indicate the unfavorable healing at the base of the pocket due to the lack of any subgingival treatment.

Periodontal diseases are bacterial infections and there- fore the aim of the periodontal therapy is to eliminate or control the periodontopathic bacteria. Direct subgingival delivery of methylene blue in different concentrations should be performed to further investigate the potential antimicrobial effect of soft lasers in human periodontal disease. Dosimetric factors are also of critical importance [15,35]. The essential question is whether soft laser can provide equal or improved treatment over conventional methods in terms of antimicrobial effects.

We do feel that more research is required to effectively determine optimal treatment parameters/regimens for the signi®cance of applying a new treatment method which is low cost, not painful, apparently harmless, and technically

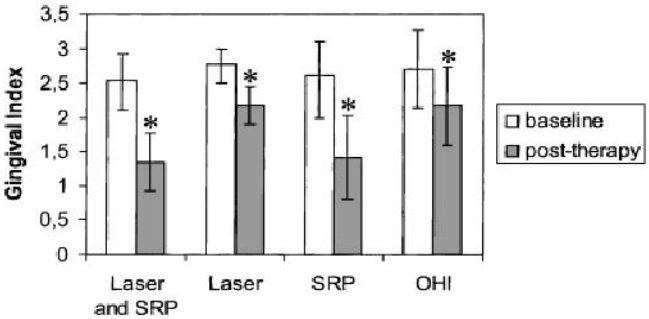

Fig. 2. Gingival index values at baseline and post-therapy.

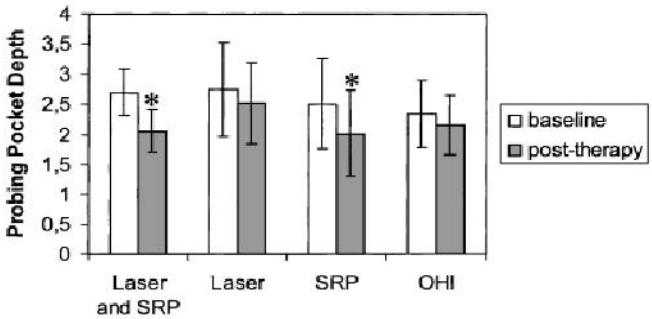

Fig. 4. Probing pocket depths (mm) at baseline and post-therapy.

TABLE 5. Comparison of Pre- and Post-Therapy Changes (Mean Æ SD) in Clinical Parameters Among Four Groups

Parameters	SRP and laser	Laser	SRP	OHI
Plaque index	1.60 Æ 0.47	0.71 Æ 0.36	1.57 Æ 0.27	0.64 Æ 0.28
Gingival index	1.03 Æ 0.65	0.60 Æ 0.57	1.17 Æ 0.68	0.53 Æ 0.42
Bleeding on probing	60 Æ 28	17 Æ 8	50 Æ 25	20 Æ 9
Probing pocket depth	0.66 Æ 0.43	0.23 Æ 0.18	0.49 Æ 0.29	0.19 Æ 0.14

*P ` 0.05.

SRP, scaling and root planing; OHI, oral hygiene instruction.

an easy treatment to perform should not be overlooked. If the in vitro bactericidal effectiveness of dye/soft laser can be achieved in vivo, low power lasers in conjunction with photosensitizer may be useful in the treatment of in¯ammatory periodontal diseases.

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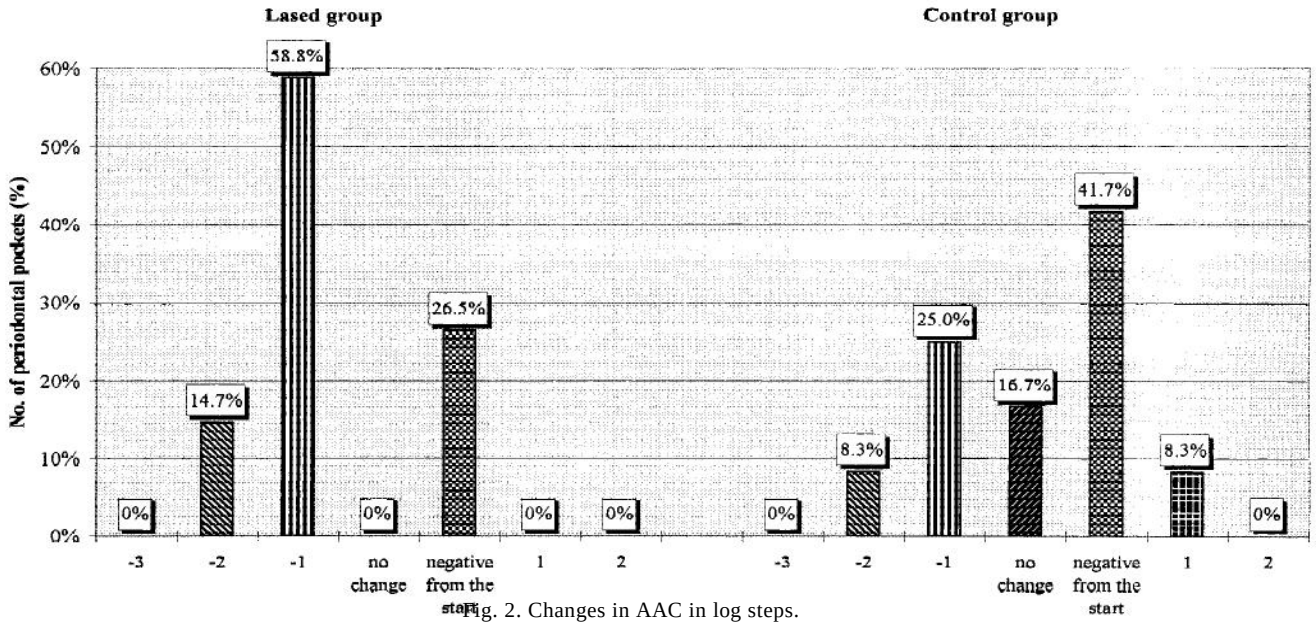


Fig. 2. Changes in AAC in log steps.

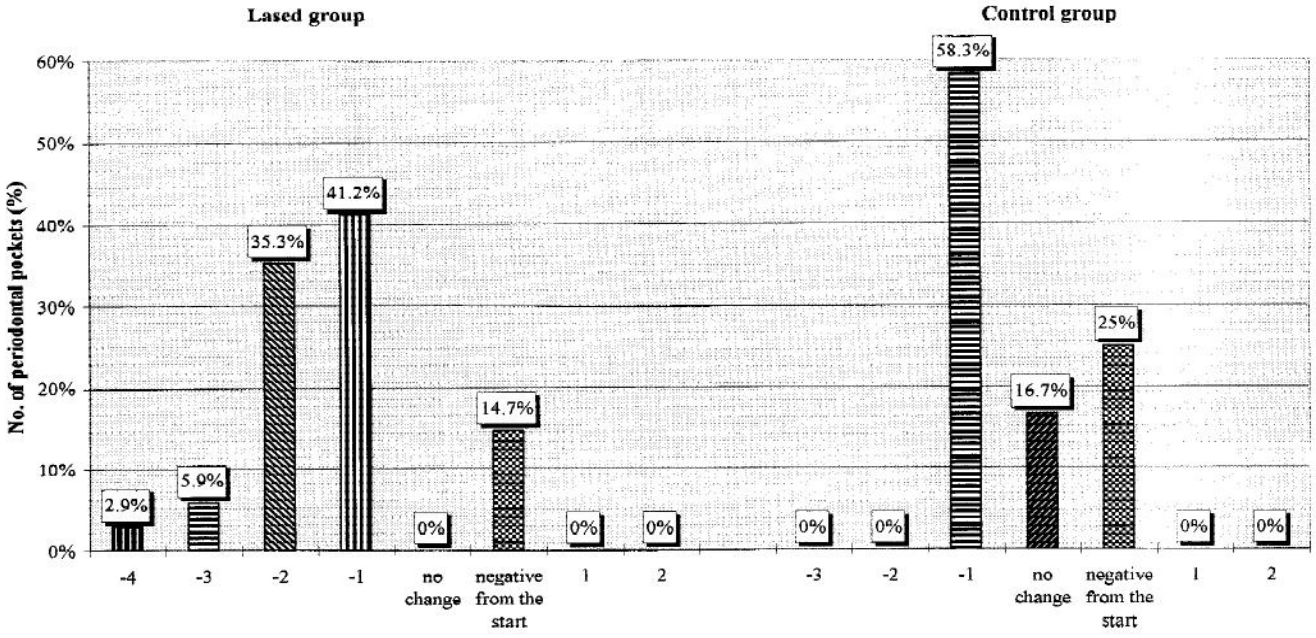


Fig. 3. Changes in Pi in log steps.

log steps. Consistent results were seen in 16.7% and in 8.3%, a deterioration of the results by two log steps.

Figure 5 illustrates the changes in the papillary bleeding index (PBI). The values improved in 96.9% of the lased patients and remained the same in 3.1%. PBI improved in 66.7% of the controls and remained consistent in 33.3%.

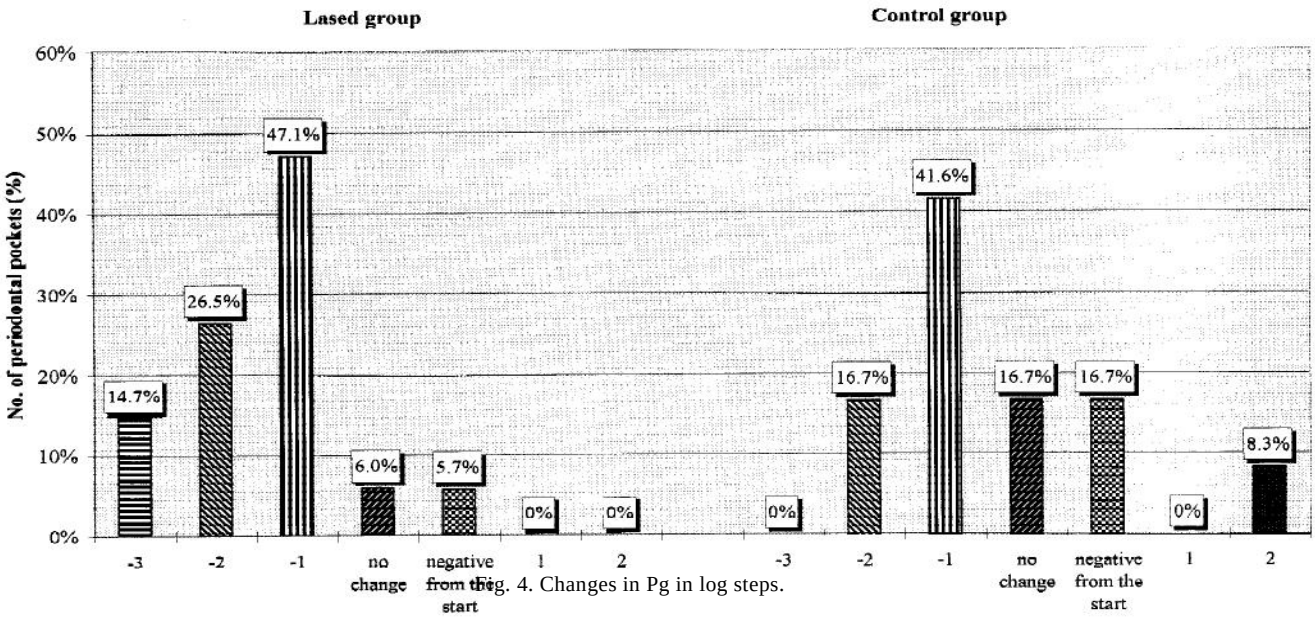


Fig. 4. Changes in Pg in log steps.

Figure 6 shows the changes in the depth of all approximal periodontal pockets for both the lased and the control groups. The teeth were subdivided into anterior teeth, premolars and molars to facilitate a better comparison. Figure 6 clearly shows that the number of periodontal pockets whose depth decreased in comparison to the initial value was markedly greater in the lased

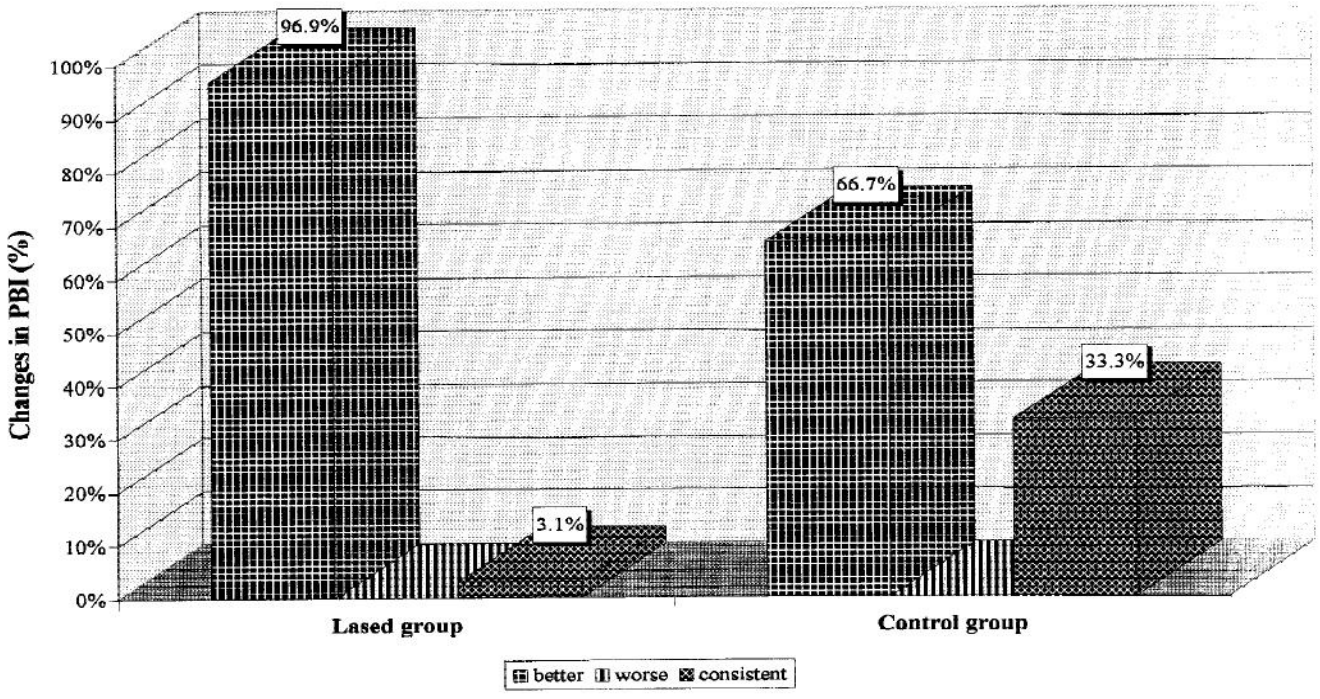


Fig. 5. Changes in PBI.

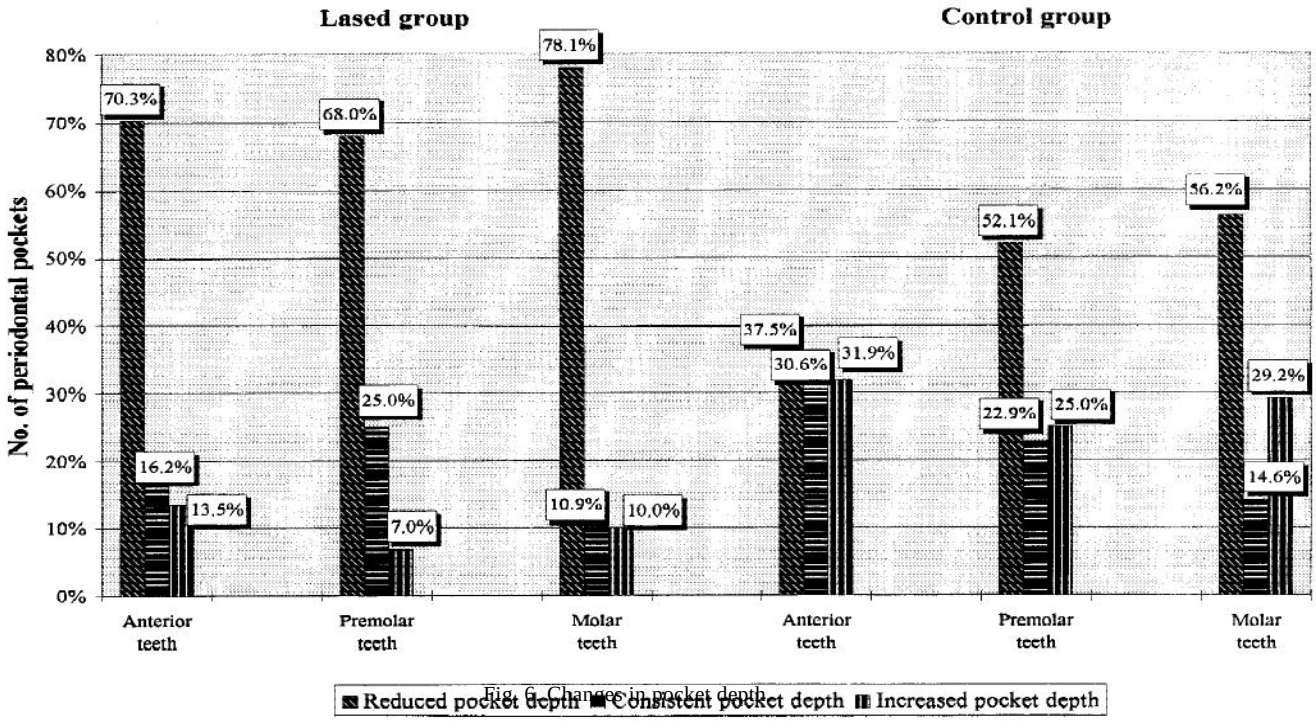


Fig. 6. Changes in pocket depth.

group than in the control group. The control group, on the other hand, showed more periodon- tal pockets with an increased pocket depth than did the lased group.

Figure 7 allows a comparison of the mean periodontal pocket depths, showing the initial and final values separately for the anterior, premolar, and molar regions, as well as a comparison be- tween the lased group and the control group.

In the lased group, the mean periodontal pocket depth decreased from 3.9 mm to 2.6 mm, especially in the molar region. Furthermore, the mean periodontal pocket depth in the premolar region decreased by 1 mm in this group. In the anterior region, the values decreased from 2.5 mm to 1.6 mm.

In the control group, the mean initial peri- odontal pocket depth in the molar region was around 3 mm and decreased to 2.6 mm after 6 months. The periodontal pocket depth in the pre- molar and molar regions was reduced by 0.1 mm and 0.2 mm, respectively.

DISCUSSION

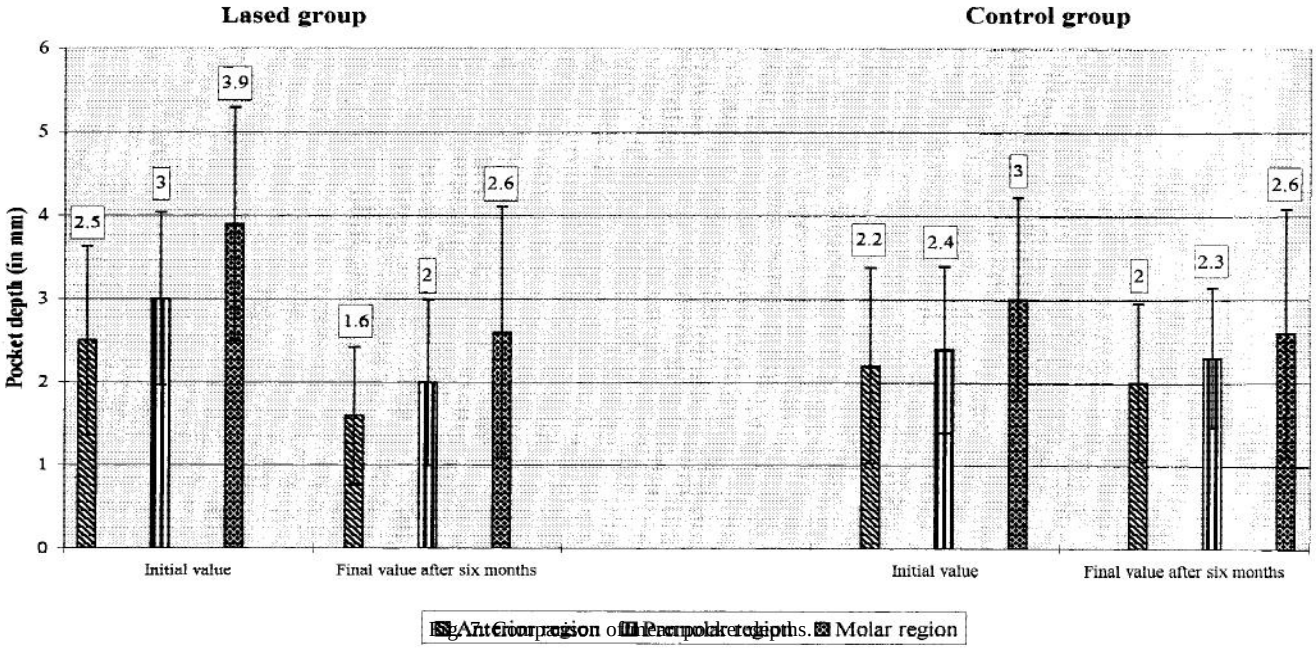
Most publications dealing with laser treat- ment of periodontal tissues cover the usage of the Nd:YAG laser. However, we expect the diode laser to have similar properties as the Nd:YAG laser that emits radiation within the infrared range at a very similar wavelength.

The effect of laser irradiation on certain tis- sues depends on both the wavelength of the laser and the absorbing capacity of the lased tissue. A study by Gold et al. [3] demonstrated that the application of the Nd:YAG laser for curettage of the pocket epithelium does not cause damage to the underlying tissue layers. Histologic sections revealed complete removal of the pocket epithe- lium without necrosis and carbonization of the connective tissue structures in 83% of the cases.

A theoretical paper by Rastegar et al. [4] comparing the application of a high-power diode laser (810 nm) and a Nd:YAG laser (1,064 nm) for tissue coagulation showed that both lasers had similar effects.

However, the heat building up at a depth of 0.2 cm in the prostatic tissue of a dog during ir- radiation with a diode laser was almost 1.5 times that caused by the Nd:YAG laser. This means that the diode laser radiation was absorbed mainly by the superficial prostatic layers.

Because desmodontal tissue is very well sup-



plied with blood, it is of interest to see to what extent diode laser radiation is absorbed by blood. Rastegar et al. [4] examined the absorption of la- ser radiation by oxygenated and deoxygenated blood and found an absorption of 4.5 cm^{-1} and a penetration of 2.2 mm in both. A comparison of the absorption values of other tissues examined in that study (liver, heart, prostate) revealed that the greatest absorption occurs in oxygenated and deoxygenated blood. It can thus be concluded that tissue that is very well supplied with blood too shows a high absorbing capacity.

Morlock et al. [5] observed melted and reso- lidified porous globules consisting of root mineral substance at the root surface following Nd:YAG laser treatment. The impressions in the root ce- mentum had a mean depth of 20-30 m. Infrared spectroscopic examinations carried out by Spen- cer et al. [6] revealed a decrease in the protein/ mineral ratio of the root surface following Nd:YAG laser treatment. Cobb et al. [7] reported a significant reduction in periodontopathic bacte- ria. However, the cementum surface was dam- aged by the high energy levels of 1.75 W and higher in vivo. Ineffective and patchy removal of deposits on the root surface was observed that was associated with areas of cratering and melt- down. Wilder-Smith et al. [8] were able to elimi- nate the smear layer on root-planed surfaces without inducing hard tissue microstructural damage. The intra-pulpal temperature increased to 22°C and the surface temperature to 36°C. Zach and Cohen [9] found that a temperature rise as small as 5.5°C can damage pulpal vitality.

Horton and Lin [10] indicated that subgingi- val application of the pulsed Nd:YAG laser should be at least equally effective in reducing recoloni- zation of specific bacterial species as scaling and root planing, less effective in removing calculus, and without any difference regarding measure- ments of probing depth and attachment loss.

According to Radvar et al. [11], Nd:YAG- laser-induced damage to the root surface also de- pends on the treatment method used. Only when the laser beam is guided parallel to the root sur- face it does not cause damage to the root, whereas perpendicularly applied laser radiation damages the root surface.

As far as bacterial reduction in periodontal pockets is concerned, the diode laser is expected to have a disinfecting thermal effect on bacteria that is basically limited to the root surface. The ther- mal effect of the laser beam is based on the ab- sorption of radiation by tissue and subsequent transformation of laser energy into heat. Tissue absorbs a certain amount of laser radiation per volume and transforms it into a certain amount of energy, depending on the exposure time used. The

amount of energy absorbed depends on the type of tissue irradiated and the wavelength of the laser.

The diode laser is not expected to cause damage to the pulp when operated in pulsed mode and at an output power of 2.5 W since White et al. [12] described only a negligible temperature rise within the pulp during irradiation with a Nd:YAG laser.

Laser light is supposed not only to eliminate bacteria but also to inactivate bacterial toxins diffused within root cementum [13].

However, recent studies by Radvar et al. [10] examining the irradiation of periodontal pockets with the Nd:YAG laser at a pulse energy of 80 mJ and 50 mJ revealed no significant bacterial reduction in periodontal pockets following laser treatment. Tseng and Liew [14] observed a significant reduction in bacterial counts; complete inhibition of all anaerobes was observed in teeth lased at output powers greater than 1 W and 20 pps.

The wavelength of their lasers ranged around 1,064 nm. Although the Nd:YAG laser is similar to the diode laser, it leads to a temperature rise in markedly deeper tissue layers, whereas most of the diode laser radiation is absorbed by superficial layers, thus having a better effect on sites affected by periodontal disease. However, the actual mechanisms of all possible laser bacteria interactions still have to be scrutinized.

The effectiveness of scaling and root planing in the treatment of periodontal disease to reduce bacterial plaque on the root surface is universally accepted [15]. Sbardone et al. [16] reported that diseased sites treated with a single episode of scaling and root planing exhibited a microflora similar to that in healthy sites at 7 days after treatment. However, the treated sites were repopulating with potentially pathogenic microbes at 21 days after treatment. Lin et al. [17] indicated that subgingival treatment with the Nd:YAG laser without anesthesia is more effective in reducing or inhibiting recolonisation of Actinomyces for up to 28 days than is root planing.

In the present study, the diode laser was used as supplementary treatment aimed to reduce or eliminate bacteria but not for calculus removal or pocket curettage. Observations at 7 days after laser treatment without scaling and root planing showed early recolonization by a variety of microbial morphotypes [7]. Lin et al. [18] showed that subgingival use of the Nd:YAG laser is less effective in removing calculus than is root planing.

Because the effects of laser treatment on periodontal tissue basically depend on the wave- length, pulse energy, frequency, and spot size used, we consider the diode laser an interesting alternative to conventional IR lasers in periodontal treatment. Furthermore, lasing is a treatment modality that is finding very good acceptance with patients because it involves minimal pain.

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