Peri-implant Care of Ailing Implants with the Carbon Dioxide Laser

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One of the many applications for which lasers have been proposed in implant dentistry is for the decontamination process. The purposes of this study were to assess possible alterations in titanium implants in vitro and in vivo by use of the carbon dioxide (CO_2) laser and to determine whether new bone formation can occur on previously contaminated implants. In vitro, temperature changes at the bone–titanium implant interface were recorded during use of a CO_2 laser-scanning system (Swiftlase). Additionally, the effects of laser irradiation on titanium implants at various power settings were examined. In 6 beagle dogs, a total of 60 implants and bony defects resulting from plaque accumulation were treated by air-powder abrasive (the conventional treatment), laser irradiation, or both. Depending on the parameters chosen, melting and other surface alterations were seen in vitro, especially in the superpulse mode. Otherwise, no alterations were found, even at high power settings in the continuous mode. In vivo, corresponding histologic examination of 4-month sections showed evidence of new direct bone-to-implant contact after laser-assisted therapy, especially when the implants had been treated concomitantly with submerged membranes. These results support the hypothesis that peri-implant defects can be treated successfully by laser decontamination without damaging the surrounding tissues in the dog model. Nevertheless, further investigations will be required to determine the clinical efficacy of the treatment. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:659–667)

Key words: *dental implants, lasers, peri-implantitis*

Numerous applications for dental lasers have been proposed for both clinical use and experimental purposes. A new indication might be the sterilization of exposed implant surfaces to rehabilitate ailing implants. However, not all laser systems available in dentistry are of value in this regard. Bida[1] reported that neodymium:yttrium-aluminum-garnet (Nd:YAG) laser irradiation on an implant collar, using a power setting of 3.0 W at 20 pulses per second, resulted in slight pitting of the surface. Moreover, Block and coworkers[2] noted that the potential exists for Nd:YAG laser irradiation to melt and even to remove the surface layer from plasma-coated titanium implants. From these studies it was concluded that the use of Nd:YAG lasers in implant-uncovering procedures or peri-implant gingival surgery should be considered inherently "unsafe" for such procedures.[3]

In contrast, carbon dioxide (CO_2) laser energy is not absorbed to any significant extent by metallic surfaces, which reduces the potential for damage to the metallic implant surface and for thermal injury to underlying tissues.[3,4] It has also been shown that CO_2 laser irradiation has an important potential for sterilization because of its excellent absorption in water.[5] Therefore, the CO_2 laser has also been recommended for applications in implant dentistry, which include uncovering implants at second-stage

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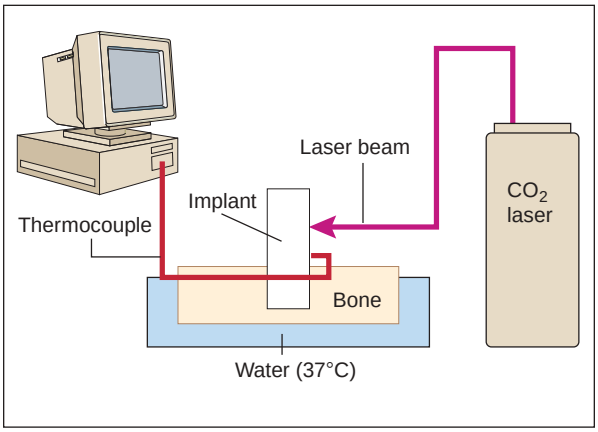

Fig 1 Experimental setup in vitro. The implant-bearing bone was fixed in a water bath, assuring that the level of immersion could not reach the marginal rim of the bone with the thermocouple in the implant-bone interface.

surgery and decontamination of exposed implant surfaces.[3,6] However, comparatively little is known about the effect of CO_2 laser energy on dental implants or the surrounding tissues when this device is used for the decontamination process. Accordingly, the purpose of this study was to assess the effects of CO_2 laser irradiation on the titanium itself and on ailing osseointegrated implants in vitro and in vivo.

MATERIALS AND METHODS

Dental Laser

The CO_2 laser employed in the present study (Model 20 C, Sharplan Company, Freising, Germany) emits a beam of monochromatic light with a wavelength of 10.6 µm. This model has a power output range from 1 to 20 W and can be operated in continuous wave (CW), pulsed, or so-called superpulsed (SP) modes of laser beam delivery. In the SP mode, mean power is generated by increasing the frequency of pulses; the energy of each single superpulse is 20 mJ. For example, the lowest mean power setting of 0.5 W is generated by 25 pulses of 20 mJ within 1 second.

A handpiece with a focus length of 125 mm was used. In the focus, the spot has a diameter of 200 µm. To keep the spot a consistent size during the irradiation, a reference pointer was mounted to the handpiece. In addition, an accessory system, the Swiftlase scanner (Sharplan Company), was used. This system was developed for the purpose of reducing tissue carbonization by sweeping a focused CO_2 laser beam in 0.1 seconds over an area with a diameter of 3.0 mm (resulting in a total area of 7.06 mm^2). Consequently, the time spent by the laser beam on each individual point of this area is less than 1 ms.

To determine the value of the system in the treatment of peri-implantitis, several in vitro studies were performed. The studies included measurements of the interface temperature during the lasing process and scanning electron microscopy of the lased implant surfaces.

Evaluation of Thermal Effects

In the first part of the in vitro study, an "ailing" implant decontamination protocol was simulated. This was achieved by placing an 11-mm-long plasma-sprayed Frialit-2 titanium implant (Friadent AG, Mannheim, Germany) into a freshly resected pig mandible.[7,8] A T-type thermocouple (University of Technology, Department of Electronic Techniques, Munich, Germany) measuring 0.5 mm in diameter was positioned 1 mm underneath the marginal level of the bone in the interface and allowed to contact bone and implant simultaneously. Along the implant surface, the lased zone ended 1 mm above the marginal rim of the bone. The implant-bearing bone was fixed in a 37°C water bath. Care was taken to ensure that the zone with the thermocouple was not immersed. Thus, the water could not direct much of the heat generated by the laser away from the thermocouple, which might have compromised the results. The model system was stabilized at room temperature prior to beginning the irradiation procedure. Temperature changes were recorded using a personal computer connected to the thermocouple (Fig 1).

Power and exposure time were varied according to the following experimental design. Irradiations were performed in both the CW and in the SP modes. In both modes, exposure times of 5 and 10 seconds were tested. The power was raised in 0.5-W steps up to the maximum wattage. At each step, only the mean of 3 temperature measurements was allowed.

Regarding the lased area of 3.0 mm in diameter, the mean power densities in the CW mode ranged from 7 Wcm^{-2} to a maximum of 283 Wcm^{-2}, and in the SP mode from 7 to 99 Wcm^{-2}. However, in the SP mode, maximum power spikes of 250 W were available because of the very short pulse duration of 80 µs.

At an exposure time of 5 seconds, the fluences (ie, the energy densities) in the CW mode ranged from 35 Jcm^{-2} to 1.4 $kJcm^{-2}$ (and from 70 Jcm^{-2} to 2.8 $kJcm^{-2}$ at an exposure time of 10 seconds). In the SP mode, the energy densities ranged from 35 to 99 Jcm^{-2} at an exposure time of 5 seconds (and from 70 to 198 Jcm^{-2} at an exposure time of 10 seconds).

Scanning Electron Microscopy

In the second part of the in vitro study, new standard 15-mm plasma-sprayed implants with a diameter of 3.8 mm (Frialit-2) were removed from their containers and lased at those power levels that had caused a rise in temperature up to 47°C. The samples were examined in a scanning microscope (JEOL USA, Peabody, MA) to visualize the entire surface of the lased implants.

In Vivo Study

Experimental Setup. Six 2-year-old female beagle dogs from the same pedigree were used in this study. Five 11-mm-long titanium plasma-sprayed Frialit-2 implants (Friadent AG) were placed bilaterally in the premolar and molar region of the mandibles, for a total of 60 implants. The implants were uncovered 3 months after placement. After 4 weeks of oral hygiene, standardized radiographs were obtained to determine the distance from the rim of the implant to the marginal bone crest on the mesial and distal aspects of each implant. A Siemens X-ray machine (Siemens AG, Bensheim, Germany) with a cone length of 25 cm was used to take the radiographs. A custom-made film holder was fixed to the cone as well as to the abutments, which were screwed into the implants. Each film was positioned with the aid of an acrylic resin guide. Agfa Dentus M 2 films (Agfa, Mortsel, Belgium) were used with an exposure time of 0.2 seconds at 7 mA and 60 kV. The films were developed in a Periomat developer for 5 minutes at 20°C (Dürr Dental, Bietigheim-Bissingen, Germany).

After the radiographs were taken, cotton floss ligatures were positioned around the implants.[9] Gross plaque accumulation around the implants was allowed undisturbed for 3 months, resulting in circumferential peri-implant bone defects. The ligatures were removed, and for 2 weeks a daily oral hygiene regimen was performed prior to the surgery. New standardized radiographs taken before the surgical intervention revealed that between 30% and 50% of the peri-implant bone had been lost.

The surgical treatment consisted of granulation tissue removal, including decontamination of the implant surface in 3 different ways. Twenty implants (group 1) were decontaminated conventionally by an air-powder abrasive[10] (Prophy-Jet, Dentsply, York, PA) for 60 seconds. Another 20 implants (group 2) were decontaminated by laser treatment alone (continuous wave, 2.5 watts, duration of 12 times 5 seconds). The last 20 implants (group 3) were treated conventionally by the Prophy-Jet for 60 seconds and then lased with the specified parameters for another 60 seconds.

In each hemimandible, only 1 mode of treatment was performed. To evaluate the effects of augmentative means, in each group, 3 nonresorbable membranes of the same type were positioned (Gore-Tex Augmentation Material Oval 4, W. L. Gore & Associates, Flagstaff, AZ). Since each group consisted of 4 hemimandibles, 3 hemimandibles each received 1 membrane, whereas the fourth hemimandible, selected randomly, did not. The position of the membrane within the 5 implants of each membrane-treated hemimandible was also selected randomly.

After surgery, a healing period of 4 months was permitted. Before the animals were sacrificed, standardized radiographs were taken again to determine the bone gain by radiographic means.

Histology, Histometry, and Radiography. After the 4-month healing period, the animal heads were fixed by vascular perfusion with 2% glutaraldehyde following a carotid artery "cut-down" procedure. The mandibles were block-resected and the undecalcified histologic sections were prepared and analyzed according to the technique of Donath and Breuner.[11] The initial section thickness of 300 µm was reduced to approximately 20 µm with the Exakt grinding unit (Exakt Cutting-Grinding System, Exakt Apparatebau, Norderstedt, Germany). The sections were stained with toluidine blue and examined in transmitted and polarized light. With this technique, old bone stains pink, whereas newly formed bone stains blue because of its higher protein content. The difference in color allows for easy distinction of old and new bone.

After histologic observations were made, computer-assisted histometry was performed to determine the size of the former bone defect and the amount of bone reappositioned. Therefore, the specimens were photographed (Ektachrome 100 HC daylight, Eastman Kodak, Rochester, NY). The resulting transparencies were scanned (Sprint Scan 35, Polaroid, Munich, Germany) using the Micrografics Picture Publisher 4.0 (Microsoft, Munich, Germany) and stored as bitmap data on a personal computer (Intel 80486 DX 2/66 16 Mbyte, Beaverton, OR). Special software (Adobe Photoshop 2.0.1, Adobe Systems Inc, Edinburgh, Great Britain) allowed computer-aided histometry. Measurements were recorded from the mesial and distal aspects of each implant to evaluate the amount of reappositioned bone. The length of the implant that was embedded in new bone was determined by measuring the distance between the most apical level of new bone in direct contact with the implant surface to the most coronal level of new bone in direct contact with the implant surface; distances of areas

Table 1 Defect Depths and Reapposition of Regenerated Bone in Submerged, Dehisced, and Membrane-Treated Implants

	Group 1				Group 2				Group 3			
Parameter	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Depth of defect (mm)	1.70	0.80	0.00	2.90	1.70	0.90	0.10	3.70	1.70	0.50	0.90	3.30
Bone gain (mm)												
Radiographs												
Submerged implants	0.46	0.41	–0.30	1.10	0.94	0.50	0.10	1.60	0.77	0.50	–0.10	1.80
Dehisced implants	0.53	0.64	–0.30	1.90	1.10	0.83	0.20	2.90	0.33	0.46	–0.30	0.90
Membrane-treated implants	1.60	0.77	1.00	2.60	1.93	0.26	1.50	2.20	1.45	0.49	0.70	2.10
Histometry												
Submerged implants	0.84	0.71	0.00	2.20	1.00	0.52	0.40	1.90	0.82	0.52	0.00	2.20
Dehisced implants	0.24	0.42	0.00	1.30	0.38	0.49	0.00	2.00	0.37	0.41	0.00	1.20
Membrane-treated implants	1.20	0.71	0.20	1.90	1.18	0.81	0.00	2.20	1.10	1.00	0.00	2.40

This quantitative analysis of bone defect depths and bone gain was carried out with radiographic and histometric methods. Group 1: Conventional therapy with an air-powder/abrasive for 60 seconds; Group 2: Laser-assisted treatment (CW 2.5 W; 12 times 5 seconds); Group 3: Decontamination first with an air-powder abrasive and then lasing with the specified parameters.

Table 2 Defect Depths and Average Reapposition of Regenerated Bone in Groups 1, 2, and 3, Excluding Membrane-Treated Implants

	Group 1				Group 2				Group 3			
Parameter	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Depth of defect on radiographs (mm)	1.70	0.80	0.00	2.90	1.70	0.90	0.10	3.70	1.70	0.50	0.90	3.30
Bone gain on radiographs (mm)	0.48	0.49	–0.30	1.90	1.20	0.75	0.10	2.90	0.70	0.51	–0.30	1.80
Bone gain in histometry (mm)	0.64	0.68	0.00	2.20	0.62	0.58	0.00	2.00	0.75	0.52	0.00	2.20

Group 1: Conventional therapy with an air-powder abrasive for 60 seconds; Group 2: Laser-assisted treatment (CW 2.5 W; 12 times 5 seconds); Group 3: Decontamination first with an air-powder abrasive and then lasing with the specified parameters.

without direct contact to the bone were then measured and subtracted. Since the lengths of the implants were known, the distances measured could be easily converted to their actual dimensions in millimeters.

The radiographs were measured conventionally using a caliper. At each implant, the distance between the coronal rim of the implant and the most apical level of bone in contact with the implant was measured at the mesial and distal aspects. These distances were measured both on the radiographs that were taken when the implants were uncovered, and also on the radiographs taken just after the cotton floss ligatures were removed. Consequently, the difference could be determined at each implant aspect, indicating the depth of defect at this aspect. With regard to the statistical analysis, the differences were averaged to obtain a mean value for the defects of each group, ie, the mean bone loss caused by the cotton floss ligatures (Tables 1 and 2).

To assess the amount of newly formed bone with radiographic methods, the distances described were measured at all aspects on the radiographs that were obtained 4 months after therapy and compared with the distances found on the radiographs taken just before surgery. As a result, the difference could be determined at each implant aspect, indicating the bone gain at this aspect. Again, for the statistical analysis, the bone gain observed was averaged in each therapy group.

Statistical Analysis

Statistical analysis was performed using a commercial computer program (Microsoft Excel, version 97, Munich, Germany). Data are presented as

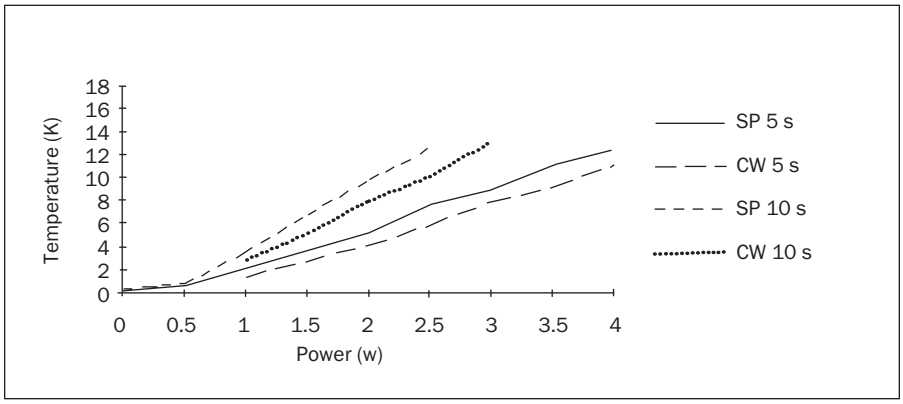

Fig 2 Effect of continuous (CW) and superpulse (SP) laser beams on implant temperature. Temperature response curve for the increase in interface temperature as a function of variations in wattage (0 to 4 W) and exposure time (5 and 10 seconds).

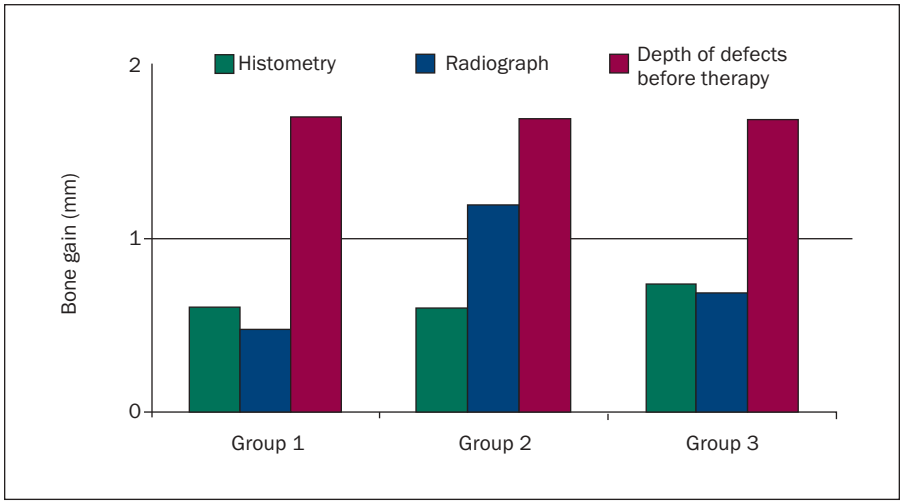

Fig 3 Average bone gain in groups 1, 2, and 3 (not including membrane-treated implants). With regard to the radiographic measurements, there was a statistically significant difference between all 3 therapy groups in bone gain. Nevertheless, the difference could not be confirmed by the histometric analysis.

means ± standard deviation or as counts or proportions. Two-tailed Student *t* tests permitted comparison of the reappositioned bone in the 3 treatment groups. A *P* value less than .05 in the 2-tailed test was considered to indicate statistical significance.

RESULTS

Thermal Effects

Figure 2 shows the temperature changes that were incurred when the implant was subjected to laser energy. It can be seen that the scanning system caused a minimal rise in temperature when used at low power settings, even at exposure times up to 10 seconds. With CW irradiation, a power of 2.5 W could be used without thermal damage to the surrounding bone. Considerably higher temperature increases were observed at all power levels with SP irradiation.

Scanning Electron Microscopy

The surface sections of all CW-irradiated plasma-sprayed titanium implants maintained the typical structure of the plasma spray layer with no sign of thermal damage. Accordingly, CW irradiation did not appear to exert adverse effects on the surface properties. However, SP irradiation resulted in sufficient heat accumulation at the surface of the implant to melt the plasma-sprayed titanium, thereby reducing or eliminating the surface porosity, with resultant microfracturing.

Histologic Observations

In group 1 (conventional decontamination), minimal new bone formation was observed (Fig 3). The

Fig 4a Implant after conventional therapy (group 1). Minimal new bone formation is indicated by an arrow (toluidine blue; magnification ×5).

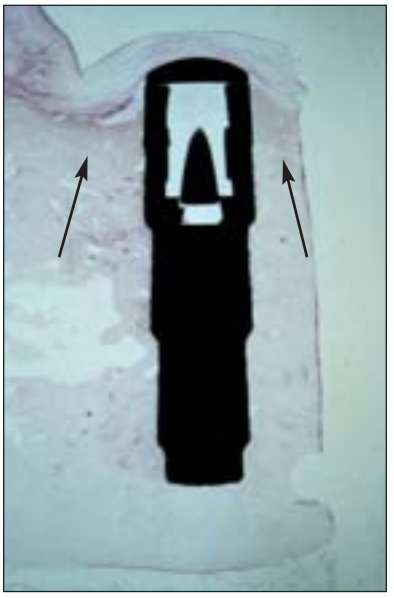

Fig 4b Implant after laser-assisted therapy (group 2). Large areas of newly formed bone are in direct contact with the implant (new bone stained darker than old bone; *arrows*) (toluidine blue; magnification ×5).

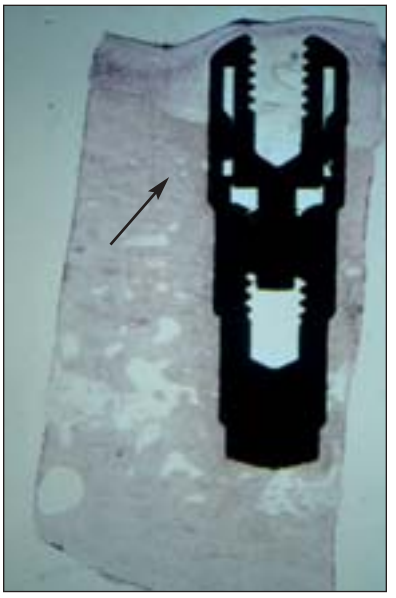

Fig 4c Implant after combination treatment (group 3). Large amounts of new bone can be seen *(arrow)* in direct contact with the formerly contaminated implant surface (toluidine blue; magnification ×5).

specimens of laser-assisted groups 2 and 3 demonstrated large amounts of rapidly formed lamellar bone, with active bone formation still ocurring. Some areas of the previously contaminated implant surfaces showed evidence of new direct bone-to-implant contact without an intervening band of connective tissue (Figs 4a to 4c). In the 40 laser-treated implants, no signs of thermal damage to the surrounding bone could be found.

In group 1, 14 implants were still submerged; in group 2 only 10 were submerged; and in group 3 a total of 17 implants were submerged. In other words, in group 1, 6 implants had dehisced; in group 2, 10 implants had dehisced; and in group 3 only 3 implants had dehisced. With respect to the differences between submerged implants, dehisced implants, and membrane-treated implants, greater amounts of new bone formation occurred in all 3 groups of submerged implants, as compared with dehisced implants. In all 3 groups, the best results were obtained with the submerged membrane technique. In the 2 laser groups, however, almost complete filling of the defects was seen (Figs 5a to 5c). At higher magnification, direct contact between newly formed bone and the previously contaminated implant surface (group 2) was clearly visible (Fig 6).

Radiographic and Histometric Observations

The standardized radiographic technique allowed evaluation of mean bone loss caused by the cotton floss ligatures and mean reappositioned bone 4 months after therapy. Mean bone loss was very similar in each group before the therapy (1.7 mm), which is of importance when comparing the post-treatment levels of bone increase (Fig 3; Tables 1 and 2).

Radiographically, the amount of reestablished bone-to-implant contact was significantly greater in both laser-treated groups (groups 2 and 3) than in the conventionally treated group 1 ($P \leq .002$ and $P \leq .01$, respectively). With respect to the 2 laser-treated groups, laser therapy alone (group 2) resulted in significantly more bone reapposition than laser therapy performed in combination with the conventional technique (group 3) ($P \leq .002$) (Table 3).

In the histometric evaluation, however, no statistically significant differences could be detected between the 3 therapy groups (Table 3). The most

Fig 5a Section of an implant after conventional therapy (group 1) that was also treated by a nonresorbable membrane. New bone has been formed up to the level of the cover screw. Reappositioned bone ends at the roughened surface *(arrow)* (toluidine blue; magnification ×5).

Fig 5b Section of an implant after laser-assisted therapy (group 2), which was concomitantly treated with a nonresorbable membrane. New bone has been formed up to the level of the cover screw. Reappositioned bone *(arrow)* ends at the roughened surface, as in the section shown in Fig 4a (toluidine blue, magnification ×5).

Fig 5c Section of an implant after combination treatment (group 3) and additional treatment with a nonresorbable membrane. New bone has formed up to the level of the cover screw. Reappositioned bone *(arrow)* can be seen even on the smooth portion of the implant surface (toluidine blue; magnification ×5).

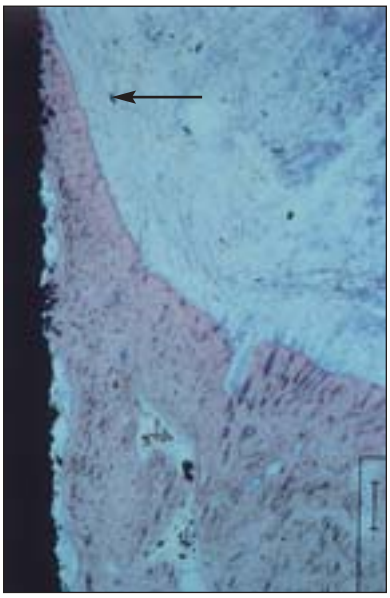

Fig 6 Implant after laser-assisted therapy (group 2). Large areas of newly formed vertical bone *(arrow)* are in direct contact with the implant (new bone stained darker than old bone, implant on the left in black). Connective tissue can be seen in the upper right part of the figure (toluidine blue; bar = 50 µm).

Table 3 Statistical Analysis According to Student *t* Test (All Tests 2-Tailed)

Group comparison	Mean bone gain ± SD (mm)	z value	Difference significant?
Radiographs			
Group 2 (n = 32)/ Group 1 (n = 35)	1.20 ± 0.75/0.48 ± 0.49	5.34	Yes ($P \leq .002$)
Group 3 (n = 34)/ Group 1 (n = 35)	0.70 ± 0.51/0.48 ± 0.49	2.47	Yes ($P \leq .01$)
Group 2 (n = 32)/ Group 3 (n = 34)	1.20 ± 0.75/0.70 ± 0.51	3.70	Yes ($P \leq .002$)
Histometry			
Group 2 (n = 33)/ Group 1 (n = 35)	0.62 ± 0.58/0.64 ± 0.68	–0.17	No
Group 3 (n = 33)/ Group 1 (n = 35)	0.75 ± 0.52/0.64 ± 0.68	1.19	No
Group 2 (n = 33)/ Group 3 (n = 33)	0.62 ± 0.58/0.75 ± 0.52	–0.73	No

With regard to the radiographic measurements, there was a statistically significant difference between all 3 therapy groups in bone gain. Nevertheless, this difference could not be confirmed by the histometric analysis.

extensive bone reapposition was found in the membrane-treated defects (Tables 1 to 3; Fig 3).

DISCUSSION

Under the conditions of this study, laser-assisted decontamination of exposed implant surfaces did not appear to have adverse effects on the "reosseointegration" of so-called ailing implants in the dog model. In fact, previously contaminated implant surfaces showed evidence of "reosseointegration." However, laser parameters are of notable interest.

The results of the present in vitro studies indicated that SP irradiation had adverse effects on the surface properties of lased implants. Consequently, SP irradiation cannot be recommended for peri-implant care. To understand this result, the fluences must be taken into consideration. The differences are obvious even at the lowest mean power settings of 0.5 W: with CW irradiation, energy is applied continuously to the focus spot area of 0.031412 mm^2, resulting in a fluence of 1.59 kW cm^{-2}. However, in SP irradiation, an energy of 20 mJ is applied with each single pulse to the focus spot area of 0.031412 mm^2, resulting in a fluence of 63 Jcm^{-2}. A spike power of 0.78 MW cm^{-2} is applied because of the short pulse durationof 80µs.

As a result of the weak thermal conductivity of titanium (λ_{Ti} = 22 W/m K, λ_{Au} = 316 W/m K), the generated heat dissipates relatively slowly and is increased by the next superpulses. This mechanism accounts very well for the melting revealed by scanning electron microscopy and also the different increases in temperature yielded at the interface in the CW mode and in the SP mode. It should be remembered that, in vivo, the maximum permissible temperature increase is 7°C (ie, the difference between the body temperature of 37°C and 44°C, the temperature at which bone is irreversibly damaged). Compared to CW irradiation, SP regularly caused a 2-degree increase at the same mean power level. Under the conditions of the very narrow safety margin of 7°C, an increase of 2 degrees means a rise of 28%, which could easily result in irreversible thermal damage to the bone. Accordingly, the tempereature increase in the SP mode can be considered to be substantially higher.

Based on the results of the in vitro study, it can no longer be stated that, in general, CO_2 laser irradiation is safe when applied to titanium implants. This observation is in agreement with the most current literature. Rechmann and coworkers[4] irradiated various dental implants. The first micromorphologic changes occurred after irradiation with a frequency-doubled Alexandrite laser at an average fluence of 0.8 Jcm^{-2}. On use of the Er:YAG laser, the average fluence for ablation was found to be 7 Jcm^{-2}. Dental implants subjected to pulsed CO_2 laser irradiation showed no signs of ablation (energy fluences were unfortunately not reported). Nevertheless, the authors assumed that higher spike pulse powers may also alter the surface in accordance with that seen in the present study.

Results of the in vivo study, however, emphasize that the laser parameters chosen for the decontamination can be considered "safe" for such procedures and for the regeneration capacity of the surrounding bone. When the 3 therapy groups were compared, the results of the radiographic and histometric analyses differed. Similar differences were also obtained in a previous study on the treatment of peri-implantitis with the submerged membrane technique; even though almost no new bone formation could be found histologically, the radiographically analyzed bone height increased slightly after therapy.[12] These differences may result from false radiographic diagnosis, as described earlier by Keller.[13] However, it should be kept in mind that computer-aided histometry enables high-resolution imaging. Therefore, distances without direct bone-to-implant contact could be subtracted readily. With the radiographic analysis, because of the poor resolution, a similar procedure was not possible. These aspects could explain the differences between the histometric and radiographic results. Nevertheless, the present study provides histologic evidence of the potential for bone regeneration after CO_2 laser irradiation.

Previous studies have demonstrated that air-spray instrumentation and a supersaturated solution of citric acid are the most effective factors in the decontamination process.[9,14] However, sterilization cannot be achieved with these methods. Thus, the submerged membrane technique might not have been effective in facilitating new bone regeneration in the dog model.[12] In another study, the submerged membrane technique provided interesting data on bone reapposition.[9] However, peri-implant bone defects were generated surgically and not by ligature-induced inflammation, which encumbers comparison of results.

CONCLUSION

Radiographic and histologic data of the present study suggest for the first time that CO_2 laser irradiation, alone or in combination with air-powder

abrasives and submerged membranes, can be employed for the purpose of implant sterilization and regeneration of moderate amounts of reappositioned bone in the dog model. This area requires further investigation to evaluate whether additional techniques, such as the use of bone morphogenetic proteins, can promote more complete filling of peri-implant bone defects.

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