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ORIGINAL ARTICLE

Nonsurgical treatment of moderate and advanced periimplantitis lesions: a controlled clinical study

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Abstract The aim of this controlled, parallel design clinical study was to evaluate the effectiveness of an Er:YAG (erbium-doped:yttrium, aluminum, and garnet) laser for nonsurgical treatment of periimplantitis lesions. Twenty patients, each of whom displayed at least one implant with (a) moderate and (b) advanced periimplantitis (n=40 implants; IMZ, ITI, Spline Twist, ZL-Duraplant, Camlog), were randomly instrumented nonsurgically using either (1) an Er:YAG laser (100 mJ/pulse, 10 Hz) device (LAS) or (2) mechanical debridement using plastic curettes and antiseptic therapy with chlorhexidine digluconate (0.2%) (C). The following clinical parameters were measured at baseline, 3, 6, and 12 months after treatment: plaque index, bleeding on probing (BOP), probing depth, gingival recession, and clinical attachment level (CAL). Mean BOP improved significantly in both groups at 3, 6, and 12 months (a− lesions: P<0.001 and b− lesions: P<0.01, respectively). After 3 and 6 months, the mean reduction of BOP was significantly higher in the LAS group when compared to the C group (a− and b− lesions: P<0.01 and P<0.05, respectively). At 3 and 6 months, both groups revealed significant CAL gains at a− and b− lesions (P<0.01, respectively). In both groups, however, the mean CAL at a− and b− lesions was not significantly different from the respective baseline values at 12 months (P>0.05, respectively). Although treatment of periimplantitis lesions with LAS resulted in a significantly higher BOP reduction than C, its effectiveness seemed to be limited to a period of 6 months, particularly at b− lesions.

Keywords Dental implant · Periimplantitis · Nonsurgical treatment · Laser/therapeutic use · Clinical trial

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Introduction

Today, the term periimplant disease is collectively used to describe biological complications in implant dentistry, including periimplant mucositis and periimplantitis. While periimplant mucositis includes reversible inflammatory reactions located solely in the mucosa adjacent to an implant, periimplantitis was defined as an inflammatory process that affects all tissues around an osseointegrated implant in function resulting in a loss of the supporting alveolar bone [1]. Because microbial colonization plays a major etiological role [6, 32], it was assumed that the removal of bacterial plaque biofilms from the implant surface is a prerequisite for the therapy of periimplant infections [29, 42]. In recent years, several maintenance regimens and treatment strategies (i.e., mechanical, chemical) have been proposed for the treatment of periimplant infections [14, 28, 35]. Mechanical debridement is usually performed using specific instruments made out of materials less harder than titanium (i.e., plastic curettes, polishing with rubber cups) to avoid a roughening of the metallic surface which in turn may favor bacterial colonization [3, 13, 25, 34]. Because mechanical methods alone have been proven to be insufficient in the elimination of bacteria on roughened implant surfaces, the adjunctive use of chemical agents

(i.e., irrigation with local disinfectants, local or systemic antibiotic therapy) has been recommended to enhance healing after treatment [14, 28]. Although air–powder flow was also successfully used for implant surface decontamination in vitro, there are limitations in the application because it can lead to microscopically visible alterations of the implant surface and be associated with an increased risk of emphysema [20, 47]. Recently, in addition to these conventional tools, the use of different laser systems has also been proposed for the treatment of periimplant infections. As lasers can perform excellent tissue ablation with high bactericidal and detoxification effects, they are expected to be one of the most promising new technical modalities for treatment of failing implants [9, 43]. However, recent in vitro studies have demonstrated that, in an energy-dependent manner, only the CO_2 (carbon dioxide) laser, the diode laser, and the Er:YAG (erbium-doped:yttrium, aluminum, and garnet) laser may be suitable for the irradiation of implant surfaces because their specific wavelength is poorly absorbed by titanium and subsequently the implant body temperature did not increase significantly during irradiation [17, 18, 33, 37]. Regarding the effect of lasers on titanium, the Nd:YAG laser is not suitable for implant therapy because it easily ablates the titanium irrespective of output energy [18, 33]. So far, bactericidal effects on textured implant surfaces in vitro were only reported for the CO_2 and Er:YAG lasers [16, 19, 20]. Because neither CO_2 nor diode lasers were effective in removing plaque biofilms from root surfaces or titanium implants, both types of lasers were only used in addition to mechanical treatment procedures [4, 9, 38, 46]. In contrast, several investigations have reported on the promising ability of the Er:YAG laser for subgingival calculus removal from periodontally diseased root surfaces without producing major thermal side effects to adjacent tissue [2, 10, 41]. Preliminary experimental and clinical results have also shown that an Er:YAG seemed to be capable of effectively removing plaque and calculus from both smooth and rough titanium implants without injuring their surfaces [26, 36, 39]. Most recently, the results of a pilot study have also indicated that nonsurgical treatment of periimplantitis with an Er:YAG laser may lead to significant clinical improvements [40]. However, these results were only based on a short-term observation period of 6 months. Furthermore, there are currently no data evaluating the effectiveness of nonsurgical treatment of periimplantitis with respect to initial disease progression. Therefore, the aim of this controlled, parallel design clinical study was to evaluate the effectiveness of an Er:YAG laser or plastic curettes and antiseptic therapy for nonsurgical treatment of moderate and advanced periimplantitis lesions over a period of 12 months.

Materials and methods

Study population

Twenty partially and fully edentulous patients suffering from periimplantitis were included in this study (n=40 implants). Each patient was given a detailed description of the procedure and was required to sign an informed consent before participation. The study protocol was approved by the local ethics committee. Periapical radiographs were taken using the long-cone parallel technique to estimate the extent of marginal bone loss, as measured from the bone crest to the most coronal bone-to-implant contact, at baseline and after 12 months. A summary of the study population is presented in Table 1.

The criteria needed for inclusion were: (1) presence of at least one screw-type implant with radiological evidence of (a) moderate and (b) advanced periimplant bone loss, (2) periimplant probing pocket depths (a) >4 mm and (b) >7 mm on at least one aspect of the implant, (3) signs of acute periimplantitis [i.e., bleeding on probing (BOP), purulence], (4) no implant mobility, (5) presence of keratinized periimplant mucosa, (6) no systemic diseases that could influence the outcome of the therapy, (7) no periimplantitis treatment during the last 6 months, (8) no systemic use of antibiotics during the last 6 months, and (9) a good level of oral hygiene (plaque index (PI) <1 [23]). Patients reporting to smoke only occasionally were not considered as smokers [45]. According to the given definition, there were no smokers included in the present study. Hollow cylinder implants were excluded from the study. The classification and distribution of a− and b− lesions in both groups at baseline are summarized in Table 2.

In particular, the following implant systems were included: IMZ (Twin Plus)® (Dentsply Friadent, Mann-

Table 1 Study population and mean age (years±SD) of patients/implants at baseline in both groups

	LAS	C
Total number of patients	10	10
Woman	6	5
Man	4	5
Mean age of patients	56±14	52±11
Partial edentulous	8	8
Fully edentulous	2	2
Total number of implants	20	20
IMZ (Twin Plus)®	2	2
ITI (SLA, TPS)®	6	2
Spline Twist (MTX)®	6	8
ZL-Duraplant (Ticer)®	4	4
Camlog (Screw Line)®	2	4
Mean age of implants	5.1±2.2	4.2±3.4

Table 2 Classification and distribution of implant lesions at baseline in both groups

	Moderate	Advanced
Initial PD (on at least one aspect of the implant)	4–6 mm	>7 mm
Radiographic marginal bone loss (percent of implant length)	<30	>30
Bleeding on probing (on at least one aspect of the implant)	+	+
Purulence (on at least one aspect of the implant)	+	+
LAS	10	10
C	10	10

heim, Germany)—sand-blasted and acid-etched surface (SLA), ITI (Institut Straumann AG, Basel, Switzerland)—SLA and titanium plasma flamed surfaces (TPS), Spline Twist (MTX)® (Zimmer Dental, Freiburg, Germany)—SLA surface, ZL-Duraplant (ZL Microdent, Breckerfeld, Germany)—anodic oxidation by spark discharge (Ticer)®, Camlog (Screw Line)® (Camlog, Wimsheim, Germany)—SLA surface (Promote)®.

Randomization procedure

The patients were randomly assigned to the following test and control groups according to a computer-generated protocol (RandList®, DatInf GmbH, Tübingen, Germany): (1) an Er:YAG laser device or (2) mechanical debridement and antiseptic therapy. The randomization process led to comparable mean values of all investigated clinical parameters at baseline in all groups.

Oral hygiene program

For 2 weeks before treatment, all patients were enrolled in a hygiene program and received supragingival professional implant/tooth cleaning using rubber cups and polishing paste (Zircate® Prophy Paste, Dentsply, Konstanz, Germany) and oral hygiene instructions on two to four appointments according to individual needs. Partially edentulous patients suffering from chronic periodontitis received additional scaling and root planing using hand instruments (Gracey curettes, Hu-Friedy, Chicago, IL, USA) on teeth exhibiting BOP or purulence. A supragingival professional implant/tooth cleaning and reinforcement of oral hygiene was also performed at baseline as well as 1, 3, 6, and 12 months after treatment.

Clinical measurements

The following clinical parameters were measured at baseline as well as 3, 6 and 12 months after treatment using a periodontal probe (PCP 12, Hu-Friedy): (1) PI [23], (2) BOP evaluated as present, if bleeding was evident within 30 s after probing, or absent, if no bleeding was noticed within 30 s after probing, (3) probing depth (PD) measured from the mucosal margin to the bottom of the probeable pocket, (4) gingival recession (GR) measured from the implant neck to the mucosal margin, and (5) clinical attachment level (CAL) measured from the implant neck to the bottom of the probeable pocket. The measurements were made at six aspects per implant, namely, mesiovestibular, midvestibular, distovestibular, mesiolingual, midlingual, and distolingual, by one previously calibrated investigator.

Five patients, each showing two implants with probing depths >4 mm on at least one aspect, were used to calibrate the examiner. The examiner evaluated the patients on two separate occasions, 48 h apart. The calibration was accepted if measurements at baseline and at 48 h were within a millimeter at >90% of the time.

Treatment procedures

In both groups, the treatment was performed under local anesthesia. An Er:YAG laser device (KEY 3®, KaVo, Biberach, Germany) emitting a pulsed infrared radiation at a wavelength of 2.94 μm was selected for laser treatment (LAS). The laser parameters were set at 100 mJ/pulse (12.7 J cm^{-2}), 10 Hz, and the pulse energy at the tip was approximately 85 mJ/pulse [36, 37, 40]. The laser beam was guided onto the implant surfaces under water irrigation with a specially designed periodontal handpiece (2061, KaVo, Biberach, Germany) and a cone-shaped glass fiber tip emitting a radial and axial laser beam (Fig. 1). The fiber tip was guided in a semicircular motion from coronal to apical parallel to the implant surface in contact mode.

In the C group, mechanical debridement was performed using plastic curettes (Institut Straumann AG, Basel, Switzerland) followed by pocket irrigation with a 0.2% chlorhexidine digluconate solution (Corsodyl®, GlaxoSmithKline Consumer Healthcare, Bühl, Germany) (CHX). After irrigation, a 0.2% CHX gel (Corsodyl® Gel, GlaxoSmithKline Consumer Healthcare, Bühl, Germany) was applied subgingivally in the respective periimplant pockets.

In both groups, instrumentation was carried out until the operator felt that the implant surfaces were adequately debrided. The amount of time needed for instrumentation was, on average, 6 min per implant. All treatments were performed by the same experienced operator.

Fig. 1 LAS treatment was performed in contact mode using a specially designed cone-shaped fiber tip emitting a radial and axial laser beam

In the C group, the postoperative care consisted of mouth rinses with CHX solution twice a day for 2 min over the first 2 postoperative weeks.

Statistical analysis

The statistical analysis was performed using a commercially available software (SPSS® 14.0, SPSS, Chicago, IL, USA). The primary outcome variable was CAL. Both patients from the C group, who were discontinued from the study due to persistent purulence, were excluded from the statistical analysis. Mean values of all clinical parameters were calculated for a− and b− lesions in both treatment groups, respectively (LAS: n=12 patients; C: n=10 patients). Normal distribution was looked for by the Kolmogorov–Smirnow test. The paired t test was used to compare the data (a− and b− lesions, respectively) within groups from baseline to those at 3, 6, and 12 months, while the unpaired t test was used to compare the data between groups (a− and b− lesions, respectively). The alpha error was set at 0.05.

Results

The postoperative healing was considered as generally uneventful. However, in the C group, two patients exhibiting a total of n=4 implants were discontinued from the study due to persisting pus formation between 4 and 12 weeks after treatment. All patients received further periimplantitis treatment using LAS and remained inconspicuous with respect to pus formation throughout the study period of 12 months. Furthermore, in the LAS group, the radial component of the laser beam resulted in an ablation and subsequently perforation of the buccal keratinized periimplant mucosa in one patient. After suturing, wound healing was uneventful but resulted in an increased GR (Fig. 2a,b). Box plots with outliers for the medians and Q1–Q3 quartiles of PI, and BOP at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months, are summarized in Figs. 3 and 4. In particular, mean PI remained low throughout the study period. A slight but nonsignificant increase of mean PI could be observed 3 and 6 months after treatment in both groups (P>0.05, respectively). However, at the 12-month examination, the mean PI was significantly higher at respective a− and b− lesions in both groups when compared to baseline (P<0.05, respectively) (Fig. 3). Both treatment procedures resulted in significant improvements of mean BOP at 3, 6, and 12 months after treatment (a− lesions: P<0.001 and b− lesions: P<0.01, respectively). After 3 and 6 months, the

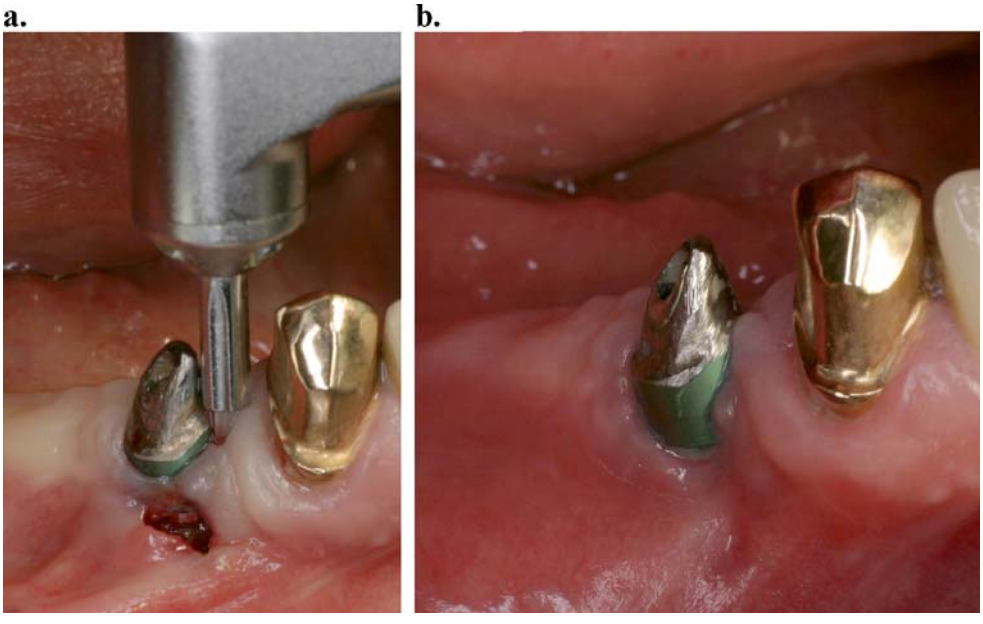

Fig. 2 In one of the patients in the LAS group, the radial component of the laser beam resulted in an ablation and subsequently perforation of the buccal keratinized periimplant mucosa (**a**). After suturing, wound healing was uneventful but resulted in an increased GR (**b**)

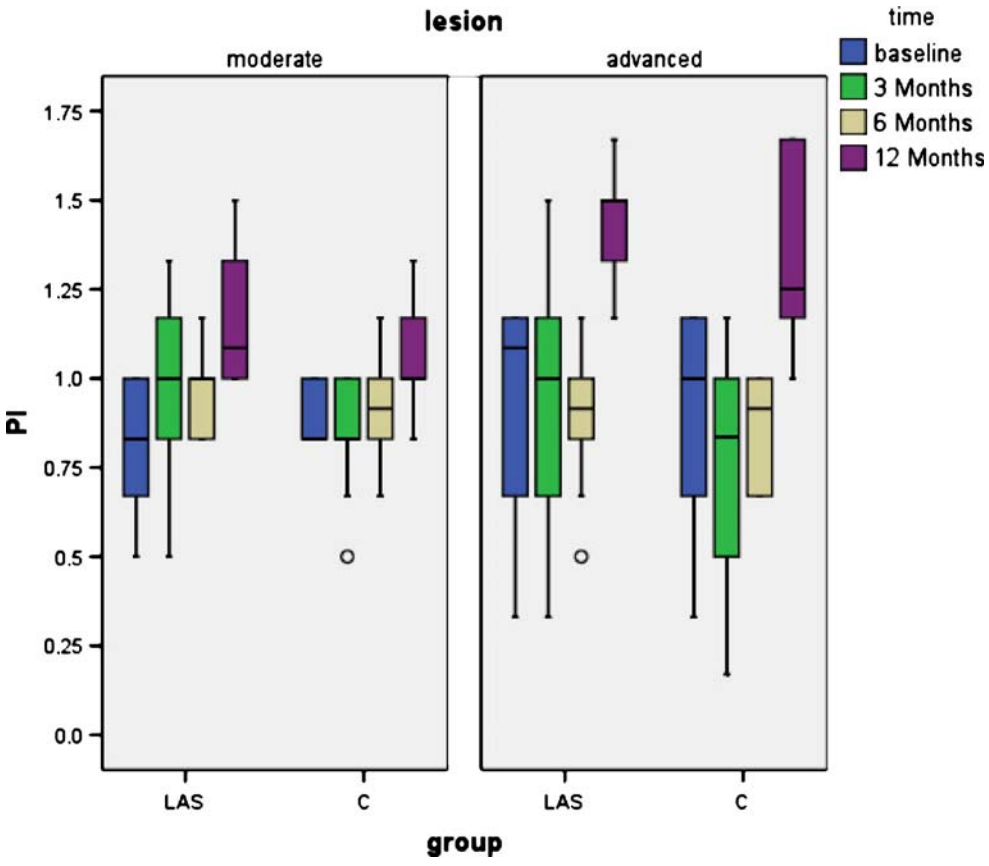

Fig. 3 Box plots with outliers for the medians and Q1–Q3 quartiles of PI at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months (LAS: *n*=10 patients; C: *n*=8 patients)

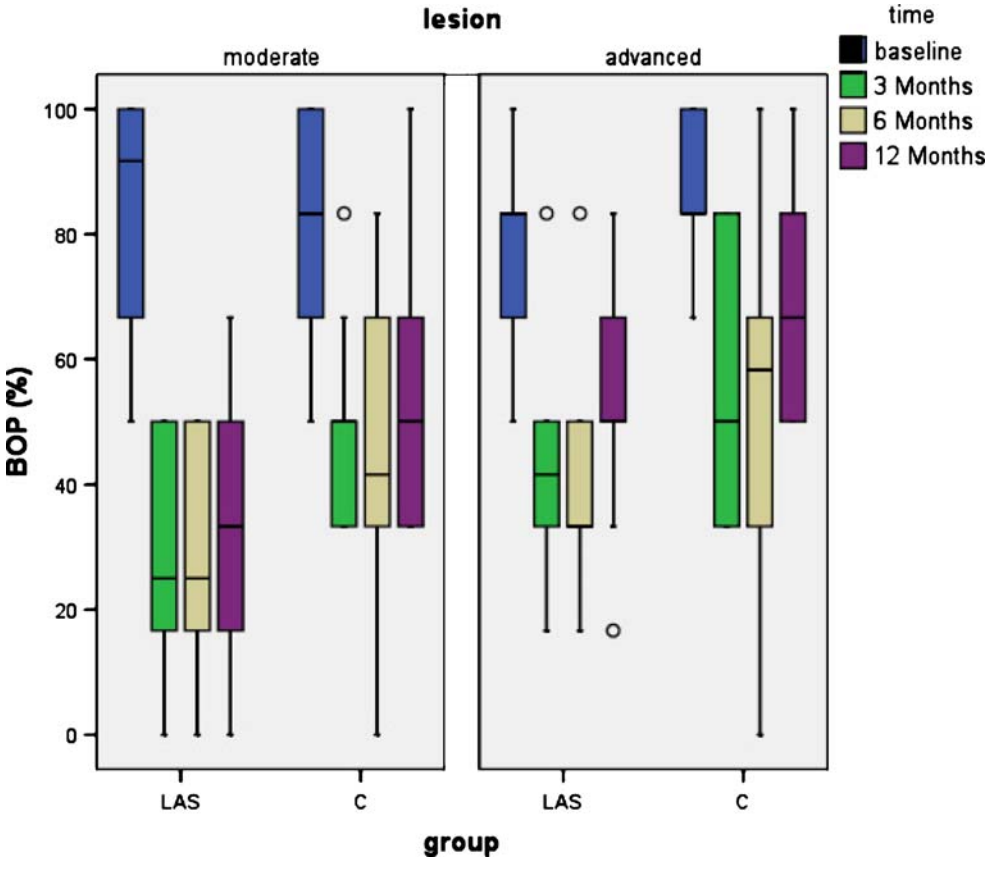

Fig. 4 Box plots with outliers for the medians and Q1–Q3 quartiles of BOP (%) at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months (LAS: *n*=10 patients; C: *n*=8 patients)

mean reduction of BOP was significantly higher in the LAS group when compared to the C group (a− and b− lesions: $P<0.01$ and $P<0.05$, respectively). However, both groups revealed a slight but nonsignificant increase of mean BOP at a− and b− lesions after 6 and 12 months after treatment ($P>0.05$, respectively). These changes appeared to be more pronounced at respective b− lesions in both treatment groups (Fig. 4).

Box plots with outliers for the medians and Q1–Q3 quartiles of PD, GR, and CAL at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months are summarized in Figs. 5, 6, and 7. In particular, after 3, 6, and 12 months of healing, both treatment procedures resulted in significant reductions of PD at a− and b− lesions in all patients ($P<0.01$, respectively). In both treatment groups, however, the respective a− and b− lesions exhibited a slight but nonsignificant increase of mean PD at 12 months after treatment ($P>0.05$, respectively). These changes appeared to be more pronounced at respective b− lesions in both treatment groups.

The mean GR increased significantly 3 months after treatment ($P<0.05$, respectively) in both groups but remained stable throughout the rest of the study period of 12 months ($P>0.05$, respectively).

Accordingly, after 3 and 6 months after treatment, both groups revealed significant CAL gains at a− and b− lesions ($P<0.01$, respectively). In both groups, however, the mean CAL at a− and b− lesions was not significantly different from the respective baseline values after 12 months of healing ($P>0.05$, respectively). In particular, at 12 months after therapy, the LAS group showed a reduction in mean PD from 4.6±0.9 to 4.1±0.4 mm at a− lesions and from 5.9±0.9 to 5.5±0.6 mm at b− lesions ($P<0.01$, respectively), and a change in mean CAL from 5.3±1.0 to 5.0±0.7 mm at a− lesions and from 6.5±1.2 to 6.3±1.1 mm at b− lesions ($P>0.05$, respectively). In the control group, the mean PD was reduced from 4.5±0.8 to 4.3±0.5 mm at a− lesions and from 6.0±1.3 to 5.6±0.9 mm at b− lesions ($P<0.05$, respectively), and the mean CAL changed from 5.1±1.0 to 5.0±0.9 mm at a− lesions and from 6.6±1.4 to 6.3±1.1 mm at b− lesions ($P>0.05$,

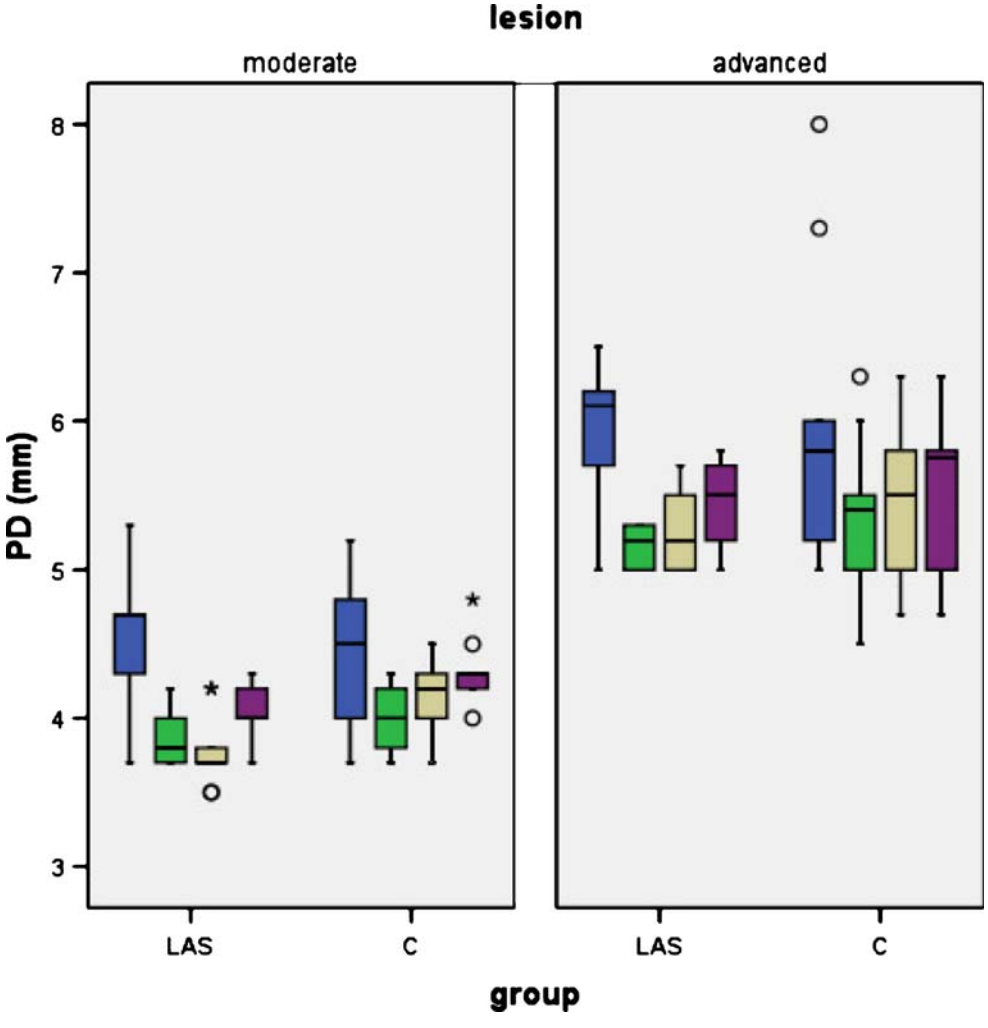

Fig. 5 Box plots with outliers for the medians and Q1–Q3 quartiles of PD at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months (LAS: $n=10$ patients; C: $n=8$ patients)

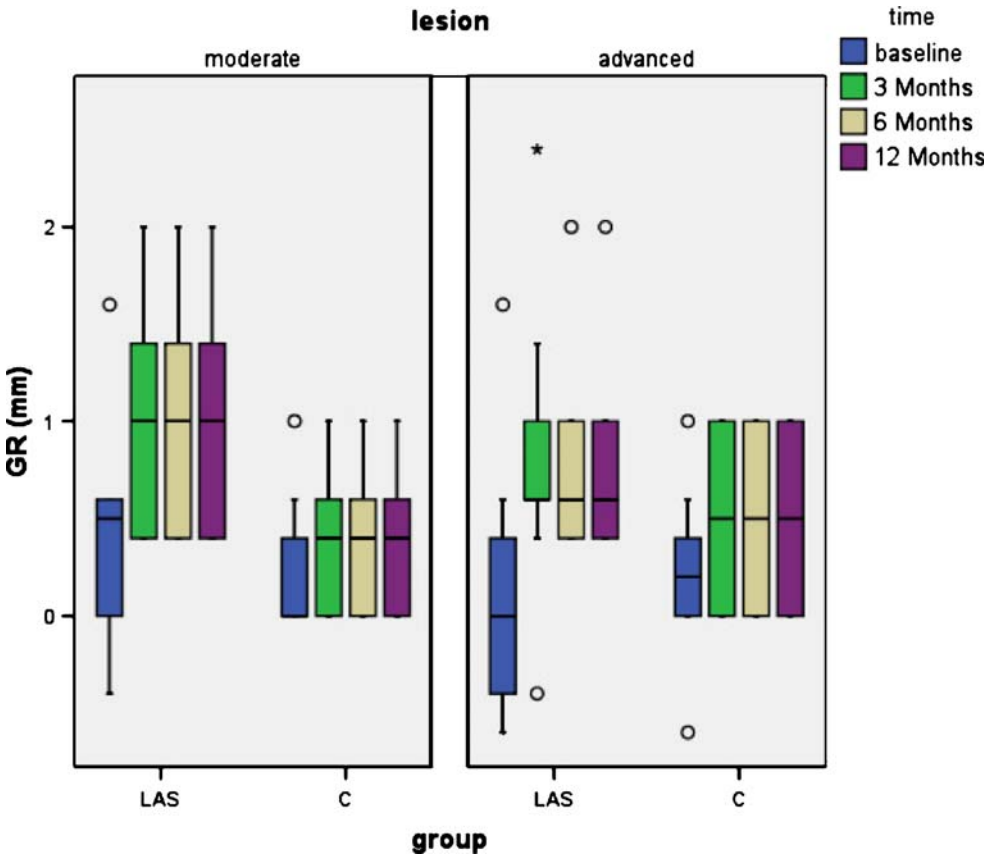

Fig. 6 Box plots with outliers for the medians and Q1–Q3 quartiles of GR at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months (LAS: *n*=10 patients; C: *n*=8 patients)

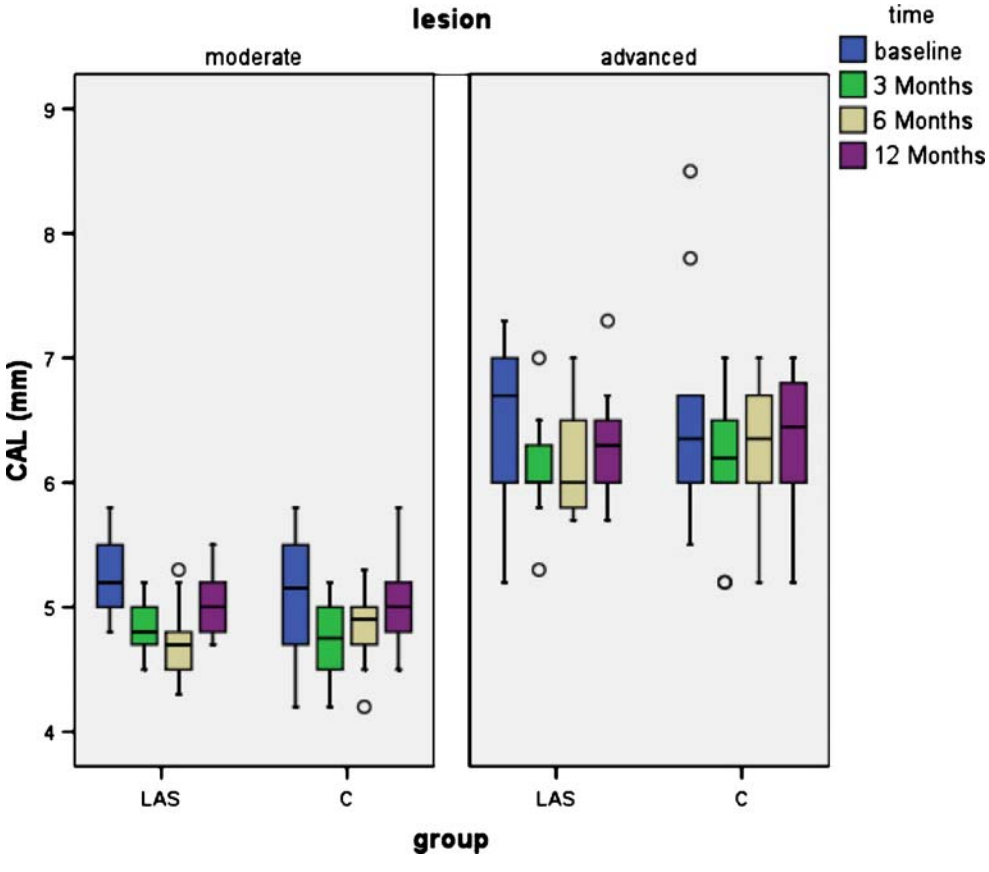

Fig. 7 Box plots with outliers for the medians and Q1–Q3 quartiles of CAL at a− and b− lesions in the LAS and C groups at baseline, 3, 6, and 12 months (LAS: *n*=10 patients; C: *n*=8 patients)

respectively). The differences between both groups at a− and b− lesions with respect to PD reductions and CAL gains were nonsignificant at 3, 6, and 12 months. Postoperative radiographs failed to demonstrate any decreases or increases of radiolucency at respective a− and b− lesions. Due to increasing BOP values and a slight loss of mean CAL after 12 months of healing, all patients in both groups were discontinued from the study and received further periimplantitis treatment using LAS and subsequent bone augmentation procedures.

Discussions

The results of the present study have shown that nonsurgical treatment of periimplantitis with both LAS and C may lead to significant clinical improvements as evidenced by reductions of BOP and PD, as well as gain of CAL. However, no differences, statistically and clinically, were observed between the two treatment modalities in terms of PD reduction and CAL gain. When interpreting the present results, it has also to be noted that treatment with LAS resulted in a significantly higher reduction of mean BOP than C. From a clinical point of view, this difference was more apparent at b− lesions. In both groups, however, a− and b− lesions revealed increasing mean BOP scores and also a loss of mean CAL between 6 and 12 months after treatment. There might be several explanations for this change. First, it has to be noted that the mean values of PI slightly increased throughout the study period, even reaching statistical significance at the 12-month examination, which in turn might have led to an inflammation and subsequently to a loss of CAL. In this context, it is important to point to the results of controlled clinical studies which have shown that the stability of CAL gain after conventional and regenerative periodontal treatment is dependent upon stringent oral hygiene [8, 48]. Second, the results from previous studies have demonstrated that subjects with a high percentage of residual deep pockets (>6 mm) after nonsurgical periodontal treatment run a greater risk of suffering from additional attachment loss than subjects with a small percentage of such residual pockets [5, 7]. However, it may be difficult to compare clinical outcomes after treatment of chronic periodontitis and periimplantitis as evidenced by measurement of PD. Indeed, the results of a recent histological study in dogs have demonstrated that the conditions for PD measurements at teeth and implants are different because the periimplant mucosa during probing was mainly displaced in the lateral direction [11, 21]. While the probe penetration tended to stop at the histological level of connective tissue adhesion at healthy and mucositis sites, it reached the base of the inflammatory lesion at periimplantitis sites [21]. To the best of our knowledge, there are no other data from case reports or controlled clinical studies reporting on the outcome of nonsurgical treatment of periimplantitis with both LAS and C up to a period of 12 months. However, the finding that nonsurgical treatment of periimplantitis with LAS or C may result on a short-term basis in clinical improvements of BOP, PD, and CAL compared to baseline is in agreement with previously reported data [15, 40]. In particular, twenty patients suffering from moderate to advanced periimplantitis lesions were randomly allocated in a parallel group design and treated with either LAS using a cone-shaped glass fiber tip (12.7 J cm^{-2}) or C. The mean value of BOP decreased in the LAS group from 83% at baseline to 31% after 6 months ($P<0.001$) and in the C group from 80% at baseline to 58% after 6 months ($P<0.001$). The difference between both groups was significant ($P<0.05$). The sites treated with LAS demonstrated a mean CAL change from 5.8±1.0 mm at baseline to 5.1±1.1 mm ($P<0.01$) after 6 months. The C sites demonstrated a mean CAL change from 6.2±1.5 mm at baseline to 5.6±1.6 mm ($P<0.001$) after 6 months. After 6 months, the difference between both groups was nonsignificant ($P>0.05$) [40]. Similar results were also reported by Karring et al. [15]. The authors compared the effectiveness of a novel ultrasonic device (Vector®) with that of carbon fiber curettes (CCU) for subgingival debridement of periimplantitis over a period of 6 months. Although the mean BOP tended to be more reduced after treatment with Vector® than with CCU, the study failed to demonstrate any significant differences in clinical improvements (i.e., BOP, PD, and bone change) between both groups. Even though subgingival debridement was performed at baseline as well as after 3 months, four of the Vector® -treated sites and merely one CCU-treated site had stopped to bleed [15]. This observation is also in agreement with the present results because C failed to reduce mean BOP to a clinically satisfying degree, particularly at b− lesions. Moreover, two patients of the C group had to be discontinued prematurely from the study due to persistent purulence. In this context, it must also be pointed out that CHX did not seem to have any beneficial effect on healing of periimplant mucositis compared to mechanical debridement alone [22, 31]. In contrast, as mentioned above, treatment with LAS resulted in a significantly higher reduction of mean BOP than C, particularly at b− lesions. There might be several explanations for the present findings. First, it must be emphasized that recent in vitro investigations have pointed to a high bactericidal potential of LAS on common dental implant surfaces, even though a complete bacterial reduction after laser irradiation could not be observed (7.62 and 15.24 J cm^{-2}) [19, 20]. However, at these laser parameters, no excessive temperature elevations (<47°C), which might have influenced bacterial

reduction additionally, were observed [19]. Furthermore, several studies have reported on the removal of plaque biofilms and calculus from both smooth and rough titanium surfaces [26, 36, 39]. In particular, it has been demonstrated that LAS (12.7 J cm^{-2}) seemed to be most suitable for the removal of supragingival early plaque biofilms grown on SLA titanium implants [39] without damaging their surfaces [37]. Highest residual plaque biofilm areas (%) were observed for C (61.1±11.4) followed by Vector® (36.8±4.5) and LAS (5.8±5.1). The differences between the groups were significant. However, all treatment procedures failed to restore the biocompatibility of previously contaminated SLA titanium surfaces as assessed by means of mitochondrial activity testing of osteosarcoma-derived osteoblasts [39]. Moreover, several studies have reported on the antimicrobial effects against periodontopathic bacteria and the removal of lipopolysaccharides by LAS radiation [12, 44, 49]. These observations, taken together with the finding that periimplantitis has been classified as a disease process associated with microorganisms known from chronic periodontitis [27], probably explain, at least in part, the significant reduction of mean BOP after LAS irradiation. In this context, it must be emphasized that BOP has been reported to play a central role in monitoring changes in periimplant tissue conditions [24]. Moreover, the inclusion of an additional microbiological test significantly enhanced the diagnostic characteristics of BOP alone [24]. Hence, it must be emphasized that a drawback of the present study was the lack of a method to monitor the subgingival microflora. Therefore, further studies are needed to evaluate the microbiological changes after LAS irradiation on the one hand and to compare the effectiveness of this treatment modality to that of adjunctive local or systemic antibiotic therapy on the other hand. All these data, taken together with the results of the present study, seem to indicate that treatment of periimplantitis by means of C does not seem to predictably result in a resolution of inflammation, particularly at b− lesions. Even though the clinical conditions were markedly improved after treatment with LAS, its effectiveness appeared to be limited to a period of 6 months, particularly at b− lesions. Consequently, it might be concluded that a single course of treatment with LAS alone may not be sufficient for the maintenance of failing implants. However, from a clinical point of view, the improvements after treatment with LAS (i.e., BOP) may serve as a sufficient basis for regenerative procedures aiming at improvement of reosseointegration. Because the surface characteristic of the implant itself has also been demonstrated to strongly influence reosseointegration after treatment of periimplantitis defects [30], it must be emphasized that the variety of different implant types and surface topographies may complicate a generalization of the present results.

Conclusion

Although treatment of periimplantitis lesions with LAS resulted in a significantly higher BOP reduction than C, its effectiveness seemed to be limited to a period of 6 months, particularly at b− lesions.

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