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Effect of Nd:YAG laser-assisted non-surgical mechanical debridement on clinical and radiographic peri-implant inflammatory parameters in patients with peri-implant disease

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ABSTRACT

Background and aim: The efficacy of neodymium-doped yttrium aluminium garnet (Nd:YAG) laser-assisted non-surgical mechanical debridement (MD) in the treatment of periimplant diseases remains uninvestigated. The aim was to assess the efficacy of Nd:YAG laser-assisted non-surgical MD on clinical and radiographic periimplant inflammatory parameters in patients with periimplant disease.

Methods: Treatment wise, 63 male patients with periimplant diseases were divided into 2 groups: Group-1 (32 patients): treatment of periimplant disease using MD alone (control group); and Group-2 ($n = 31$ patients): treatment of periimplant disease using MD with a single application of Nd:YAG laser. Peri-implant inflammatory parameters (plaque index [PI], bleeding on probing [BOP] and probing depth [PD]) were measured at baseline and at 3 and 6 months' follow-up. Periimplant crestal bone loss (CBL) was measured at baseline and at 6 months' follow-up. Statistical analysis was performed using the Kruskall-Wallis and Bonferroni *Post hoc* tests. *P*-values < 0.05 were considered statistically significant.

Results: In both groups, mean age of patients and baseline scores of periimplant PI, BOP and PD were comparable. At 3-month follow-up, scores of periimplant PI, BOP and PD were higher among patients in Group-1 compared with Group-2. At 6-month follow-up, scores of periimplant PI, BOP and PD were comparable among patients in groups 1 and 2. There was no statistically significant difference in periimplant CBL in both groups at all time intervals.

Conclusion: Nd:YAG laser-assisted non-surgical MD is more effective in reducing periimplant soft tissue inflammatory parameters than MD alone in short-term but not in long-term.

1. Introduction

Peri-implant diseases are categorized into periimplant mucositis and periimplantitis. Peri-implant mucositis is characterized by periimplant soft tissue inflammation (bleeding on probing [BOP], increased probing depth [PD] ≥ 4 mm and/or suppuration) [1,2] without any radiographic evidence of periimplant crestal bone loss (CBL); whereas periimplantitis is characterized by radiographic evidence of periimplant CBL in conjunction with periimplant soft tissue inflammation [2–4].

Traditionally, periimplant diseases are treated using either a nonsurgical or a surgical therapeutic regimen. In a nonsurgical approach, mechanical debridement (MD) of plaque and/or calculus from implant surfaces is performed; and surgical management of periimplant diseases involves placement of a particulate graft material over the osseous defect and covered a barrier membrane following MD [5–7]. The neodymiumyttrium-aluminium-garnet (Nd:YAG) laser ($\lambda = 1064$ nm), approved for treatment by the US Food and Drug Administration is being used for periodontal curettage for nearly 40 years. This is primarily due to the fact that this wavelength gets absorbed only in soft tissues such as epithelial lining of the periodontal pocket and hard tissues, for example cementum and dentin remain unaffected [8] Moreover, this wavelength has also been reported to help in reducing periodontopathogenic bacteria and granulomatous tissue formation [9–13]. Results from a short-term split-mouth, single-masked, randomized, controlled clinical trial showed that at 1-week follow-up, there was a statistically significant reduction in periodontal PD in sites treated with a single application of Nd:YAG laser as an adjunct to MD compared with sites that received MD alone [10]. Likewise, results from a 20-month follow-up clinical trial demonstrated that a single application

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of a pulsed Nd:YAG laser when used in combination with MD is significantly more effective in reducing PI, BOP and PD in patients with chronic periodontitis as compared to when MD was performed as the sole treatment protocol [9]. Moreover, it has been proposed that since the Nd:YAG laser has shorter wavelength (1064 nm) as compared to other lasers (such as carbon dioxide laser, 10,600 nm), it affects only the soft tissues such as the pocket epithelial lining [14]; and it has deep penetration depth due to high absorption by the chromophore hemoglobin [12].

Since MD with adjunct Nd:YAG laser therapy has been shown to be more effective in reducing periodontal inflammatory conditions compared with MD alone [9,10,15]; it is hypothesized that MD with a single application of Nd:YAG laser as an adjunctive therapy is more effective in the treatment of periimplant diseases compared with MD alone. Therefore, the aim of the present single blinded randomized clinical trial was to assess the effect of Nd:YAG laser-assisted non-surgical MD on clinical and radiographic periimplant inflammatory parameters in patients with periimplant disease

2. Materials and Methods

2.1. Ethical Approval

The study was approved by the Research Committee of the College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Participation was completely voluntary and volunteering participants were requested to sign a consent form. All participants were informed that they could withdraw their participation at any stage of the investigation without any consequences.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (a) signing the consent form; and (b) patients with periimplant disease (bleeding on probing on at least 30% of the periimplant sites, deepened peri-implant pockets of ≥4 mm and/or loss of supporting bone [≥3 mm] around a functional implant]). Tobacco smokers and smokeless tobacco chewers, individuals habitually consuming alcohol, patients with a history of systemic diseases, such as diabetes mellitus, acquired immune deficiency syndrome, renal disease, patients who had used antibiotics, non-steroidal anti-inflammatory drugs or steroids within the past 90 days and patients who reported to have undergone any form of dental treatment within the past 90 days were excluded.

2.3. Study Participants and Grouping

The participants were recruited from the Out Patient Department of a local oral Healthcare Center in Riyadh, Saudi Arabia. Consenting participants were randomly divided into 2 groups. Randomization was done, by tossing a coin. Participants in Group-1, underwent peri-implant MD only; and individuals in Group-2 underwent MD with a single application of Nd:YAG laser as an adjunct therapy.

2.4. Mechanical Debridement

Periimplant MD was performed by one investigator using plastic curettes. The curettes (Patterson Dental, 776-5928, NY, USA) were inserted in the peri-implant pockets and the implant surfaces were gently debrided of plaque as standard of care.

2.5. Laser Parameters

Laser irradiation was performed by a trained and calibrated investigator. Pulsed Nd:YAG laser (1064 nm) (Genius Dental, Tureby, Denmark) therapy was performed by inserting a 300 μm wide fiber into the periimplant pocket almost parallel to the implant. The fiber was then moved in a mesial-distal direction for 60 to 120 s. The laser was used at a power of 4 Watt (W) with 80 mJ energy per pulse. The pulse width was 350 milliseconds and the pulse-repetition rate was 50 Hz [9,10]. The laser was applied in the presence of air and water cooling.

2.6. Assessment of Periimplant Clinical and Radiographic Parameters

All clinical and radiographic assessments were performed by an experienced and calibrated examiner (TA) who was blinded to the study groups (*kappa* = 0.92). At baseline, peri-implant PI [16], BOP [16] and PD [16] were assessed at 6 sites per implant (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual and distolingual) in groups 1 and 2. The presence of suppuration was noted as well. The clinical parameters were reassessed at 3- and 6-month follow-up. Digital radiographs were standardized using the radiographic paralleling technique and a guiding device at follow-up and compared to the baseline evaluation. In each group, the mean mesial and distal CBL were recorded in millimeters on digital radiographs using a precalibrated software program (Scion Image, Scion Corp., Fredrick, Maryland, MA. USA). Calibration of the software was performed using the predefined implant length. CBL was measured on all implants in both groups at baseline and at 6-month follow-up. CBL was defined as the distance from the widest supracrestal part of the implant to the alveolar crest [4]. Total CBL was determined by averaging the mesial and distal scores of CBL.

2.7. Statistical Analysis

Statistical analysis was performed using a software package (SPSS v.18, IBM, Chicago, IL., USA). The Kruskal–Wallis test was used to compare the age and periimplant PI, BOP, PD and CBL among individuals in groups 1 and 2. Means and range of the aforementioned parameters were computed and for multiple comparisons, the Bonferroni *post hoc* test was performed. Study sample size was also calculated using a computer-software (nQuery advisor, Statistical Solutions, version 7.0, Saugus, MA, USA). It was estimated that with the inclusion of at least 30 patients per group, a study power of 85% (assuming a standard deviation of 1%) at a two-sided significance level of 0.05 would be achieved. Level of significance was set at $P < 0.05$.

3. Results

3.1. General Characteristics

In groups 1 and 2, 32 and 31 male individuals with mean ages of 43.6 years (31–58 years) and 40.5 years (29–60 years), respectively were included. In groups 1 and 2, a total of 39 and 35 delayed-loaded platform-switched bone level (Straumann Bone Level implants, Straumann AG, Basel, Switzerland) implants with moderately rough surfaces were placed. In both groups, the diameters and lengths of implants ranged between 3.3 and 4.1 mm and 10–14 mm, respectively. In groups 1 and 2, 33 and 31 implants, respectively, were placed in the mandible in the region of missing premolars and molars. The implants had been in function for 4.4 years (2–6.5 years) and 4.8 years (1–5.3 years) in groups 1 and 2 respectively, (Table 1). All implants had been restored with cement-retained restorations.

3.2. Periimplant Clinical and Radiographic Parameters at Baseline and at 3 and 6-month Follow-up

At baseline, mean scores of periimplant PI, BOP and PD were comparable among patients in groups 1 and 2. At 3-month follow-up, mean scores of periimplant PI ($P < 0.05$), BOP ($P < 0.05$) and PD ($P < 0.05$) were statistically significantly higher among patients in group-1 compared with those in Group-2. At 6-month follow-up, there was no statistically significant difference in the mean scores of periimplant PI, BOP

Table 1
General characteristics of the study cohort.

	Group-1	Group-2
Number of patients	32	31
Mean age in years (range)	43.6 (31–58)	40.5 (29–60)
Total number of implants placed	39[a]	35[a]
Maxilla	6[b]	4[b]
Mandible	33[b]	31[b]
Duration of implant in function in years (range)	4.4 (2–6.5)	4.8 (1–5.3)
Implant dimensions		
Diameter in millimeters	3.8–4.1	3.8–4.1
Length in millimeters	11–14	11–14

[a] Implants were platform-switched with moderately rough surfaces and were loaded approximately 4 months after placement.
[b] Implants were placed in the area of missing premolar and molars.

and PD among patients in both groups. At baseline and at 6-month follow-up, the mean CBL was comparable among individuals in groups 1 and 2 (Table 2).

4. Discussion

The present study was based on the hypothesis that that MD with a single application of Nd:YAG laser as an adjunctive therapy is more effective in the treatment of periimplant diseases compared with MD alone using plastic curettes. The present results support this hypothesis since scores of periimplant PI, BOP and PD were significantly lower among patients in Group-2 (MD + Nd:YAG laser) compared with patients in Group-1 (MD alone) at 3-month follow-up. These results indicate the periimplant soft tissue healing is significantly faster when MD is performed with adjunct Nd:YAG laser compared with MD alone. One explanation for this outcome is that MD when performed with Nd:YAG laser significantly reduces the counts of periimplant pathogenic microbes as compared to when MD is performed alone. Moreover, it has also been reported that MD with adjunct single application of Nd:YAG laser irradiation reduce the expression of proinflammatory cytokines (interleukin-1 beta and matrix metalloproteinases) in the gingival crevicular fluid of patients with periodontal disease [10]. It is therefore hypothesized that in the present study, MD with adjunct Nd:YAG laser therapy significantly reduces microbial counts and expression of proinflammatory cytokines in the periimplant sulcular fluid thereby demonstrating a significant difference among patients in group 2 compared to patients in Group-1 at 3-month follow-up. However, further studies are needed to test this hypothesis. The present results are however in contradiction with a previous study, which reported no additional benefits of Nd:YAG laser therapy in terms of reducing oral inflammation when used as an adjunct to MD [17]. Although a precise explanation in this regard is difficult to understand, this difference in outcome may most likely been associated with the different laser power used in the study by Sjöström and Friskopp [17]. In the study by Sjöström and Friskopp [17], the laser was set to 7 W, whereas in the present study, the laser power setting was lower (4 W). Studies have reported that the water-cooled Nd:YAG laser when used up to 4 W yields optimal outcomes without damaging oral tissues [18,19]. Therefore, it is highly recommended that for optimal outcomes, lasers should be used in accordance with the manufacturers' instructions and the operator should be well-trained and experienced in the field of laser dentistry.

Interestingly, there was no statistically significant difference in CBL among patients in groups 1 and 2 at 3- and 6-month follow-up compared with baseline. In both groups, CBL was approximately 2 mm at all time intervals. This finding is considered normal according to criteria set by Albrektsson et al. [20] according to which, 2 mm of CBL after implant placement is considered normal as it occurs as a result of bone remodeling after implant uncovering. Other factors that could have influenced this outcome is that all participants were systemically healthy non-smokers, were relatively young (nearly 40 years old) and had implants in function for nearly 5 years. It has been reported that the quality of bone, which hosts the implant influences primary stability and success rate of the implant [21]. Results from a recent clinical study showed that the morphology of alveolar bone significant varies between the arches with the posterior mandible exhibiting significantly higher cortical bone thickness compared with the anterior and posterior maxilla [21]. In the present study, nearly 80% of the implants in both groups were placed in the posterior mandible. Therefore, additional studies assessing CBL around implants (with and without laser therapy) with reference to location of the implant in the jaws are needed.

In the present study, plastic curettes were used to debride implant surfaces in both groups, which is in accordance with previous studies [22–24]. Moreover, it has been shown that in contrast to metallic hand instruments (made from stainless steel and titanium alloys), MD of titanium implant surfaces using plastic curettes are least likely to damage the implant surfaces during maintenance procedures [25]. Furthermore, results from *in-vitro* studies have also shown that adherence and proliferation of fibroblasts on implant surfaces scaled with plastic curettes is similar to non-treated implants [26,27]. Nevertheless, the significance of operators' skills and experience in this regard cannot be overlooked. In the present study, MD for performed by one trained and experienced investigator.

The present results are in accordance with a previous study, which showed no statistically significant differences in BOP and PD in sites treated with MD with or without Nd:YAG laser application at 6-month follow-up [28]. These results indicate that the use of Nd:YAG laser as an adjunct to MD is effective in reducing periimplant soft tissue inflammation in the short-term but not in the long-term. It is pertinent to mention that the Nd:YAG laser damages the implant surface compared to other lasers (such as the CO_2-laser) [29]. Therefore, the use of this wave length in conjunction with the treatment of periimplant diseases has to be cautious and under copious irrigation or water supply; however, evaluation s of the potential risks of risks and temperature increase of the implant body during implant irradiation should be performed in future studies. Companies promoting this wavelength for treatment of periodontal and periimplant diseases should be able to provide evidence based scientific documentation in order to avoid confusion and misinterpretation of the basic laser-tissue interactions.

A limitation of the present study is that strict eligibility criteria were imposed. For example, tobacco-smokers, smokeless tobacco chewers and individuals with systemic diseases were not sought. Studies [30–32] have reported that habitual use of tobacco products is associated with an increased expression of receptor of advanced glycation end products (RAGE) in gingival tissues; and interactions between advanced

Table 2
Periimplant soft tissue inflammatory parameters at baseline and at 3 and 6 months of follow-up.

Periimplant Parameters	Baseline		3-month follow-up		6-month follow-up	
	Group-1 ($n = 32$)	Group-2 ($n = 31$)	Group-1 ($n = 32$)	Group-2 ($n = 31$)	Group-1 ($n = 32$)	Group-2 ($n = 31$)
Mean plaque index in % (range)	52.5 (48.6–59.8)	57.3 (45.6–63.4)	17.5* (10.6–22.5)	6.3 (3.5–7.2)	6.5 (5.2–8.5)	9.6 (5.8–11.7)
Mean bleeding on probing in % (range)	48.6 (39.6–55.7)	50.3 (36.3–58.2)	16.5* (10.2–22.6)	5.5 (2.5–8.6)	8.8 (6.9–10.3)	10.5 (7.4–12.5)
Mean probing depth in mm (range)	5.6 (4–6)	5.3 (4.4–6)	4.5* (2.5–6)	2.4 (2–3)	4 (3.8–5.5)	2.5 (2–3)
Mean crestal bone loss in mm (range)	1.8 (0.8–2.5)	2.1 (1.4–2.6)	–	–	1.7 (1–2.4)	2.2 (1.5–2.7)

* Compared with individuals in group-2 at 3-month follow-up ($P < 0.05$).

glycation endproducts (AGEs) and RAGE have been shown to enhance periodontal inflammation [30–32]. Similarly, the AGEs and RAGE interactions have also been reported to be higher among immunocompromised patient, such as those with poorly-controlled diabetes mellitus [33–35]. It is therefore hypothesized that the outcomes of MD with or without adjunct Nd:YAG laser therapy are compromised in patients with systemic disease such as poorly controlled diabetes mellitus and among tobacco product users. Further well-designed randomized controlled clinical trials are needed in this regard.

5. Conclusion

Nd:YAG laser-assisted non-surgical MD is more effective in reducing periimplant soft tissue inflammatory parameters compared with MD alone in short-term but not in the long-term.

Conflict of Interest Statement

None declared.

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