Systematic Review

The Effect of a Pulsed Nd:YAG Laser in Non-Surgical Periodontal Therapy

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Background: Laser treatment may serve as an alternative or adjunctive treatment to conventional mechanical therapy in periodontics. The neodymium-doped:yttrium, aluminum, and garnet (Nd:YAG) laser has been used in periodontics. Systematic reviews aid in clinical decision-making. The aim of this study was to evaluate, in a systematic manner and after a comprehensive search of the literature, the (additional) therapeutic effects of using a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis.

Methods: The focused question for this systematic review was, "What is the efficacy of a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis, either as monotherapy or as an adjunct to non-surgical periodontal treatment?" The efficacy of this technique was compared to conventional therapy (ultrasonics and/or hand instrumentation) in removing plaque, as well as in improving clinical parameters, such as periodontal inflammation and probing depth. Articles published before May 2008 in the databases of MEDLINE/PubMed and the Cochrane Central Register of Controlled Trials were searched to identify appropriate studies. Clinical parameters of periodontal inflammation, namely, plaque, bleeding, gingivitis, probing depth, clinical attachment level, and gingival recession, were selected as outcome variables.

Results: Independent screening of the titles and abstracts of 285 PubMed and 38 Cochrane articles resulted in eight publications that met the eligibility criteria. Means ± SDs were collected by data extraction; only descriptive analysis was possible.

Conclusions: The majority of the studies analyzed showed no beneficial effect of a pulsed Nd:YAG laser compared to conventional therapy (ultrasonics and/or hand instrumentation) in the initial treatment of patients with periodontitis. The pulsed Nd:YAG laser was assessed as monotherapy and as an adjunct to non-surgical periodontal treatment; efficacy was determined by the extent of plaque removal and the reduction of periodontal inflammation. This literature review suggests that there is no evidence to support the superiority of the Nd:YAG laser over traditional modalities of periodontal therapy. *J Periodontol 2009;80:1041-1056.*

KEY WORDS

Debridement; Nd:YAG laser; periodontitis; systematic review; treatment; ultrasonics.

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The first working laser was created by Theodore Maiman[1] in 1960. This device used a crystal medium of ruby that emitted a coherent radiant light when stimulated by energy. The word "laser" is an acronym for "light amplification by stimulated emission of radiation"; lasers are categorized according to the medium used to provide atoms to the emitting system. Each type of atom can absorb photons of specific wavelengths. Therefore, each medium produces a laser beam with a single, unique wavelength.[2] Light of different wavelengths interacts differently with tissues and does not have the same absorption qualities. The first applications of lasers to dental tissue were reported by Goldman et al.[3] and Stern and Sognnaes;[4] both articles described the effects of a ruby laser on enamel and dentin.

In 1961, Snitzer[5] published the prototype of the neodymium-doped:yttrium, aluminum, garnet (Nd:YAG) laser, which emits in the infrared range of the spectrum with a wavelength of 1.06 microns. The Nd:YAG laser was further developed by Geusic et al.[6] in 1964. This laser's medium is a crystal of yttrium-aluminum-garnet doped with neodymium. It penetrates to various degrees in pigmented tissues, reaching depths ranging from 0.5 to 4 mm as a function of optical scattering, minimal absorption and reflection, and the mode of delivery. The

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depth of penetration that is characteristic of a wavelength is a critical feature that can influence its usefulness for any particular application. The 1,064-nm Nd:YAG laser light can be transmitted through an optical fiber, such that it can pass through an endoscope or be delivered intraorally using a handpiece. This allows the operator to work in a familiar setting and use contact mode for tactile sensation. The Nd:YAG laser has been recommended for various types of minor oral soft-tissue surgery.[7] It has been prescribed for use in maxillary midline frenectomies, lingual frenectomies, gingivectomies, gingivoplasties, operculum removal, and biopsies of benign lesions.[2,7-9]

Several advantages of laser treatment over conventional methods include minimal cellular destruction and tissue swelling, hemostasis, increased visualization of surgical sites, sterilization of the wound site, reduced postoperative pain, and high patient acceptance.[10] In addition, there have been some reports of nerve analgesia after Nd:YAG laser irradiation.[11] Gold and Vilardi[12] showed the efficacy of a low-power pulsed Nd:YAG laser in removing epithelium lining the periodontal pocket in humans with moderately deep pockets. In addition, the Nd:YAG laser has a bactericidal effect, suppressing or eradicating putative periodontal pathogens from periodontal pockets.[13,14]

Laser treatment may serve as an alternative or adjunctive treatment to conventional mechanical therapy in periodontics.[15] The use of a dental laser in the treatment of periodontitis is based on the purported benefits of subgingival curettage and a significant decrease in subgingival pathogenic bacteria. Such laser therapy is commonly referred to as "non-surgical."[16] A recent narrative review[16] of the literature suggested that the use of the Nd:YAG wavelength for the treatment of chronic periodontitis may be equivalent to scaling and root planing (SRP) with respect to probing depth (PD) reduction.

However, few published data compared the clinical outcomes from treatment with Nd:YAG or carbon dioxide (CO_2) laser to those from well-established procedures, such as ultrasonic scaling (US).[15] Comparative clinical studies are required to establish the potential of lasers in periodontal therapy. This is particularly true for subgingival applications, such as root debridement, soft tissue curettage, and excisional new attachment. Furthermore, clinical studies are needed to show that laser therapy is effective at treating chronic periodontitis. Systematic reviews aid in clinical decision-making. The value of a good systematic review is that it minimizes bias and provides a comprehensive and contemporary overview. Such analyses are objective in their appraisal of quality, and they are transparent, allowing others to appraise the methodology and quality of the review itself. If such conditions are met, the reader should have greater confidence in the conclusions of the review than other summaries of clinical evidence.[17]

A recent systematic review[18] on lasers in non-surgical periodontal therapy developed a search strategy and inclusion and exclusion criteria that eventually picked up only one article on Nd:YAG lasers that met the search criteria. An even more recent review[19] that evaluated the effect of laser therapy as an adjunct to non-surgical periodontal treatment lacked a reproducible search strategy. Also, it used studies with a duration of ≥12 weeks of follow-up as part of the inclusion criteria. This review also picked up only one article on Nd:YAG lasers, but not the same article as the other review. This is clearly insufficient for making firm statements about the therapeutic effects of this particular laser.

Therefore, the aim of this study was to evaluate, in a systematic manner and after a comprehensive search of the literature, the (additional) therapeutic effects of using a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis.

MATERIALS AND METHODS

Focused Questions

What is the effect of a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis, either as monotherapy or as an adjunct to non-surgical periodontal treatment? How does the pulsed Nd:YAG laser compare to conventional therapy (ultrasonics and/or hand instrumentation) in destroying plaque and in improving clinical parameters of periodontal inflammation and PD?

Search Strategy

Two Internet sources of evidence were used to search for appropriate articles addressing the focused question: the National Library of Medicine (MEDLINE/PubMed) and the Cochrane Central Register of Controlled Trials. Search criteria were designed to include any study that evaluated a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis. The databases were searched up to and including January 2009 using the terms described below. The asterisk (*) was used as a truncation symbol.

MEDLINE Search

Intervention. <([MeSH terms] lasers OR laser therapy OR [text words] laser) AND ([MeSH terms] OR neodymium OR [substance name] yttrium-aluminum-garnet OR [text words] neodymium OR neodimium OR yttrium aluminum garnet OR aluminum garnet laser OR neodymium YAG OR neodimium YAG OR Nd:YAG OR NdYAG)> AND

Outcome. <[MeSH] periodontal diseases OR dental deposits OR [text words] papillary bleeding index OR sulcus bleeding OR bleeding on probing OR gingival bleeding OR gingival index OR gingival inflammation

OR gingival diseas* OR gingivitis OR periodontitis OR periodontal diseas* OR periodontal pocket OR gingival pocket OR pocket depth OR plaque removal OR plaque index OR dental plaque OR plaque OR dental deposit OR calculus OR clinical attachment loss>.

Cochrane Library Search

Intervention. <([MeSH terms] lasers OR laser therapy OR [text words] laser) AND ([MeSH terms] OR neodymium OR [text words] neodymium OR neodimium OR yttrium aluminum garnet OR aluminum garnet laser OR neodymium YAG OR neodimium YAG OR Nd:YAG OR NdYAG)> AND

Outcome. <[MeSH] periodontal diseases OR dental deposits OR [text words] papillary bleeding index OR sulcus bleeding OR bleeding on probing OR gingival bleeding OR gingival index OR gingival inflammation OR gingival diseas* OR gingivitis OR periodontitis OR periodontal diseas* OR periodontal pocket OR gingival pocket OR pocket depth OR plaque removal OR plaque index OR dental plaque OR plaque OR dental deposit OR calculus OR clinical attachment loss>.

Eligibility Criteria

Initially, titles and abstracts resulting from the searches described above were screened independently by two reviewers (DES and FW). Subsequently, the same reviewers screened and selected the full-text articles. The following eligibility criteria were imposed: 1) randomized controlled clinical trials (RCTs) or controlled clinical trials; 2) conducted in humans with good general health (no systemic disorders), ≥18 years of age, and with periodontitis; 3) intervention: use of Nd:YAG laser as monotherapy or as an adjunct to non-surgical periodontal initial therapy; 4) control group: conventional therapy (ultrasonics and/or hand instrumentation) or placebo treatment; 5) evaluation parameters: plaque/bleeding/gingivitis/PD; and 6) the use of statistical analysis.

Only articles written in English were included. Case reports, letters, and historical reviews were excluded. Articles without abstracts, but whose titles suggested that they could be related to the objectives of this review, were also selected, so that the full text could be screened for eligibility. Any disagreements between the reviewers were resolved by discussion. Reference lists of potentially relevant studies and review articles were also searched. After the final selection of the articles by the two reviewers (DES and FW), those that fulfilled the selection criteria were processed for data extraction.

Assessment of Heterogeneity

Factors that were recorded to evaluate the heterogeneity of the primary outcomes across studies were study design and evaluation period; type of Nd:YAG laser, comparison treatment, and industry funding; and subjects and smoking.

Quality Assessment

Assessment of methodologic study quality was performed as proposed by the RCT checklist of the Dutch Cochrane Center,[20] the CONSORT statement,[21] Esposito et al.,[22] Moher et al.,[23-25] the Delphi list,[26] and Needleman et al.[27]

Statistical Analyses

Data extraction. From the selected articles, data were extracted that described the clinical effects after the use of a pulsed Nd:YAG laser in the initial treatment of patients with periodontitis compared to control treatment. Means ± SDs were extracted by the authors (DES and FW). Some of the articles provided standard errors (SE) of the mean. When necessary, the authors calculated SD based on the sample size ($SE = SD/\sqrt{N}$).

Data analysis. The studies in the final dataset were few and highly heterogeneous in terms of design, characteristics, energy settings, fiber tips, length of the observation periods, primary outcome variables, and presentation of results. This made it impossible to carry out quantitative analysis of the data and subsequent meta-analysis. Instead, a descriptive manner of data presentation was used.

RESULTS

Search and Selection Results

The MEDLINE/PubMed search resulted in 285 citations, and the Cochrane search resulted in 38 citations (Fig. 1). After removing duplicate listings of articles present in both searches, 296 titles and abstracts remained to be screened. The screening of titles and abstracts initially resulted in 11 full-text articles. Based on the full texts, three studies were excluded because they lacked a control group[28] or statistical analyses[29] or they compared Nd:YAG laser treatment to surgical flap treatment.[30] Finally, eight studies[15,31-37] were identified as eligible and were analyzed further.

Outcome Results

Assessment of heterogeneity. Information on the study characteristics is displayed in Table 1.

Study design and evaluation period. All studies had an RCT design. Four studies (III, V, VII, and VIII; Table 1) had a split-mouth design, and two studies (II and IV) had a parallel design. The design was unclear in two studies (I and VI).

Three studies (I, II, and VII) had an evaluation period of 4 to 6 weeks, and three studies (III, IV, and VI) had an evaluation period of 12 weeks. Sjöström and Friskopp[37] (VIII) evaluated patients after 4 months. The longest study (6 months) was conducted by Neill and Mellonig[34] (V). When a study presented intermediate assessments regarding the use of the Nd:YAG laser, the authors took the baseline and final evaluations into account for this review.

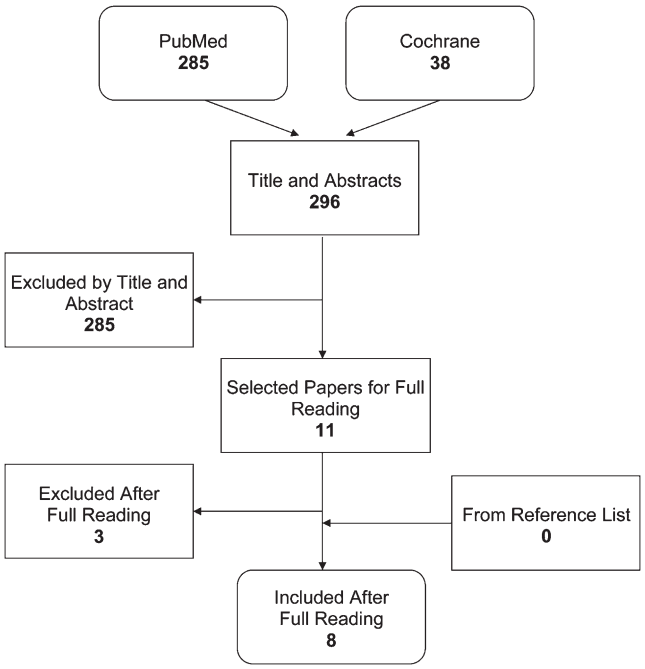

Figure 1.
Search and selection results.

Type of Nd:YAG laser, comparison, and industry funding. In the identified articles, different brands of Nd:YAG lasers were used as test products. Different energy settings, tips, coolants, contact times, and types and depth of fiber insertions were used (Table 2). The laser used by VIII was a prototype Nd:NCG laser light (1,061 nm), which, according to the manufacturer's description, is nearly identical to the Nd:YAG laser (1,064 nm).

Four (III, IV, VI, and VII) of the eight studies evaluated the Nd:YAG laser as monotherapy; two of them (studies III and VII) compared laser treatment to manual SRP, one (study IV) compared it to US, and another (study VI) compared it to a control/placebo group in which the fiber was inserted into periodontal pockets, but the sites were not irradiated (sham treatment). Five studies (I, II, III, V, and VIII) included a combined treatment trial that assessed the Nd:YAG laser in combination with supra- and subgingival debridement. Two of them (studies I and II) used a combination of manual and ultrasonic instruments. Study III also evaluated the order of treatment: Nd:YAG laser followed by SRP compared to SRP followed by Nd:YAG laser.

Basic oral hygiene education at baseline, including instructions on toothbrushing, flossing, and the use of an interdental brush, was described in only three studies (II, III, and IV). This instruction was reinforced at all subsequent visits.

All studies but three (II, V, and VI) had financial support. The grants originated from funds for the promotion of science from Tanaka Industries, Niigata, Japan (study IV); the Fundação de Amparo a Pesquisa no Estado de São Paulo, Brazil, and Procad/CAPES and Instituto Milenio Fotonica/CNPq (study I); the National Science Council, Taipei, Taiwan (study III); the Scottish Office Home and Health Department (study VII), Edinburgh, United Kingdom; and Public Dental Care, County of Stockholm, Sweden (study VIII).

Subjects and smoking. Periodontal patients were used in all studies, the definition of which varied from radiographic information to clinical parameters (Table 1). Three studies (III, VI, and VIII) evaluated single-rooted teeth, whereas one study (I) specifically treated Class II furcation defects. Study VII selected teeth with poor prognosis that were scheduled for extraction. Four studies (II, IV, VI, and VIII) selected subjects in "good general health, with no systemic diseases." The use of antibiotics during the previous months was an exclusion criterion (studies IV and VI). Only study VIII provided information about the smoking habits of the participants; their study population consisted of smokers and non-smokers. However, the effect of smoking on the study outcome variables was not analyzed.

Study quality. Quality assessment is presented in Table 3. The estimated risk for bias was high in seven of eight studies. The risk was considered moderate for study I.

Randomization, masking, and losses to follow-up. All studies mentioned random assignment to the different treatment groups, either by subject (II), split-mouth design at quadrants (III, V, VII, and VIII; Table 1), or randomization by site (I, IV, and VI; Table 1). However, the method of randomization was often unclear (studies I, III, IV, V, and VI; Table 1). Only study VIII described that patient assignment was performed by lot. Procedures for allocation concealment were not described.

One study (II) mentioned that all clinical evaluations and treatment procedures were done by the same examiner, so no masking was performed. Two studies (I and V; Table 1) self-identified as being double-masked; the others (studies III, IV, VI, VII, and VIII; Table 1) did not specify any such masking. Study VI was the only one that was truly masked in design. In the test and control groups, the fiber was inserted into periodontal pockets, but the sites in the control group were not irradiated (sham treatment). Masking of examiners and participants to protect against performance and measurement bias was assessed, although it is recognized by the authors that masking participants to interventions such as laser treatment is rare and, depending on the design of the trial, often impossible.

No loss of subjects to follow-up was reported by three studies (I, III, and IV). Only study VIII lost one

Table 1.

Overview of the Selected Studies (Nd:YAG laser) and Their Characteristics in Chronologic Order

Investigators and Title	Design and Evaluation Period	Inclusion Criteria	Intervention	Subjects (N [number of teeth])	Investigators' Conclusions
I de Andrade et al.[31] Nd:YAG laser clinical assisted in Class II furcation treatment	RCT ? Double-masked 6 weeks	All patients had received previous periodontal treatment (up to four sessions) with the exception of the molars. Chronic periodontitis; Class II furcation defects.	 Nd:YAG + SRP/US SRP/US	17 (34) ? (?) ? (?)	The Nd:YAG laser irradiation associated with SRP and the isolated conventional treatment demonstrated statistically significantly increased clinical conditions with these parameters 6 weeks after the treatment, but no statistically significant differences were observed between the groups.
II Kara et al.[32] Effect of Nd:YAG laser irradiation on the treatment of oral malodor associated with chronic periodontitis	RCT parallel No masking 4 weeks	Patients with chronic periodontitis (5 to 7 mm), radiographic evidence of bone loss, and complaining of oral malodor. No antibiotic treatment within the previous 3 months, no evidence of systemic disease that may influence oral malodor. Minimum of 20 natural teeth, PD >3 mm.	 SRP/US + Nd:YAG SRP/US	60 20 (?) 20 (?)	The data indicated a possible adjunctive role for Nd:YAG lasers in periodontal therapy.

Table 1. (continued)

Overview of the Selected Studies (Nd:YAG laser) and Their Characteristics in Chronologic Order

Investigators and Title	Design and Evaluation Period	Inclusion Criteria	Intervention	Subjects (N [number of teeth])	Investigators' Conclusions
III					
Liu et al.[33] Comparison of Nd:YAG laser versus scaling and root planing in periodontal therapy	RCT split-mouth Masking ? 12 weeks	Individuals with moderate to advanced periodontitis. No periodontal therapy within preceding 6 months; radiographic horizontal bone loss. At least one or two sites of three adjacent single-rooted teeth in each quadrant with GI ≥2, PD 4 to 6 mm, and BOP.	Nd:YAG Nd:YAG + SRP SRP + Nd:YAG SRP	8 (56) 8 (14) 8 (14) 8 (15) 8 (13)	The data suggest that SRP is more effective than laser therapy at reducing gingival inflammation. No additional benefit was found when Nd:YAG was used secondary to SRP.
IV					
Miyazaki et al.[15] Effects of Nd:YAG and CO_2 laser treatment and ultrasonic scaling on periodontal pockets of chronic periodontitis patients	RCT parallel Masking ? 12 weeks	Seeking periodontal care, free of systemic complications that could interfere with periodontal healing. No use of antibiotics during the previous 3 months; no periodontal treatment during the previous 6 months. Two or more non-adjacent teeth with interproximal PD ≥5 mm.	Nd:YAG US	18 (41) 18 (14) 18 (14)	The Nd:YAG laser was as effective as US in reducing the clinical signs of periodontitis. Both groups showed significant improvements, but no significant difference was observed between the groups.

Table 1. (continued)

Overview of the Selected Studies (Nd:YAG laser) and Their Characteristics in Chronologic Order

Investigators and Title	Design and Evaluation Period	Inclusion Criteria	Intervention	Subjects (N [number of teeth])	Investigators' Conclusions
V					
Neill and Mellonig[34] Clinical efficacy of the Nd:YAG laser for combination periodontitis therapy	RCT split-mouth Double-masked 6 months	Adult periodontitis, with PD >4 mm and radiographic bone loss.	 Nd:YAG + SRP/US SRP/US	10 (186/744*) 10 (91/364*) 10 (49/196*)	Clinical significance of these findings suggest that mechanical SRP therapy alone may not be the most effective. There are several additional areas where the adjunctive use of Nd:YAG may have an advantage over SRP alone as a mechanical approach to non-surgical therapy.
VI					
Noguchi et al.[35] Combined effects of Nd:YAG laser irradiation with local antibiotic application into periodontal pockets	RCT ? Masking ? 3 months	Seeking periodontal care; no periodontal treatment; >20 teeth; presence of four or more non-adjacent single-rooted teeth with PD >4 mm; no systemic complications; no use of antibiotics during the 6 months prior to treatment.	 Nd:YAG Control group	16 (135) ? (37) ? (32)	The mean PD and CAL of the laser group decreased significantly. There was no significant decrease either to PD or CAL in the control group.
VII					
Radvar et al.[36] An evaluation of the Nd:YAG laser in periodontal pocket therapy	RCT split-mouth Masking ? 6 weeks	Untreated chronic adult periodontitis; affected teeth of poor prognosis scheduled for extraction.	 Nd:YAG (50 mJ) Nd:YAG (80 mJ) SRP	11(80) 11(20) 11(20) 11(20)	Application of Nd:YAG failed to improve the clinical parameters of periodontal disease.

Table 1. (continued)

Overview of the Selected Studies (Nd:YAG laser) and Their Characteristics in Chronologic Order

Investigators and Title	Design and Evaluation Period	Inclusion Criteria	Intervention	Subjects (N [number of teeth])	Investigators' Conclusions
VIII					
Sjöström and Friskopp[37]	RCT split-mouth	Referred individuals, healthy from a medical standpoint, smokers and non-smokers. Periodontal breakdown, single-rooted.		26 (960*)†	Nd:NCG treatment resulted in diminished bleeding and enhanced visual control at debridement.
Laser treatment as an adjunct to debridement of periodontal pockets	Masking ?		Nd:NCG + SRP	? (484*)†	
	4 months		SRP	? (476*)†	

? = unknown/not given.
* Number of sites.
† One dropout.

subject to follow-up because the person requested to be excluded from the study. The other four studies (II, V, VI, and VII) did not provide any information about losses to follow-up.

Plaque indices and clinical parameters. Various plaque and gingivitis indices were used. Plaque was scored by the Silness and Löe[38] index in four reports (I, II, IV, and VII); it was unclear which index was used in study III (Table 4). Gingivitis was also assessed by different indices: the gingival index (GI) of Löe and Silness[39] was used by studies I, II, III, and IV, and Lobene's modified GI[40] was used by study VII (Table 5). Study V did not reference which index was used. For bleeding scores, three studies (IV, VI, and VII) used a measure of bleeding on probing (BOP); two studies (V and VIII) used the gingival bleeding index without reference (Table 6). PD was assessed in all selected studies (Table 7). Clinical attachment level (CAL) was estimated in studies I, II, IV, V, and VI (Table 8). In contrast, gingival recession (Table 9) was measured only in study I. Analyses were performed at the tooth or site level; no study provided a subject-level analysis.

Study outcomes. Study I showed a discrepancy between the text and the abbreviations presented in the tables with respect to the different indices. Data presented in the text were assumed to be correct. Similarly, study V showed an inconsistency between the text and figure with respect to CAL. Again, the text was considered correct.

Comparison of baseline and end (within groups). Five studies (III, V, VI, VII, and VIII) provided incomplete or insufficient data for two or more parameters within the groups (Tables 4 through 9).

Two (I and II) of five studies that presented plaque scores showed a significant change, and two studies (IV and VII) reported no significant change from baseline. This information could not be extracted from study III (Table 4).

In three (I, II, and IV) of four studies that provided complete data, a significant change in gingival health was observed in all groups. However, study VII did not report a significant change (Table 5).

Two studies (IV and VIII) showed a positive significant change for all groups with regard to bleeding index. However, study VII found a significant improvement only in the SRP group and not in either of the Nd:YAG groups (Table 6).

PD was significantly changed for all groups in four studies (I, II, IV, and VIII). Study VII found a significant change only in the SRP group, whereas study VI reported a significant change only in the Nd:YAG group (Table 7).

Three (I, II, and IV) of four studies with appropriate data found a significant increase in CAL in all groups, whereas study VI observed a significant change only in the Nd:YAG group (Table 8).

The only study (I) that assessed gingival recession found a tendency for this to increase in all groups, but the increase was not significant (Table 9).

Analysis between groups. Table 10 summarizes differences between the Nd:YAG laser and other strategies. Two studies (III and VI) did not provide appropriate data for comparisons between groups. In addition, studies II, IV, V, and VII presented inappropriate information for some indices. The only positive significant difference in favor of the Nd:YAG laser was presented in study V with respect to GI; however, this was not supported by three other studies (I, II, and VII)

Table 2.

Overview of the Selected Studies and Nd:YAG Laser Parameters of Interest

Investigators and Laser Brand	Energy Settings	Tip	Coolant	Contact Time	Fiber Insertion	Anesthesia
I						
de Andrade et al.[31] American Dental Technologies, Southfield, Michigan	100 mJ/pulse 1.5 W 15-Hz repetition rate Pulse duration: 150 μm Energy density: 141.5 J/cm^2	Optical fiber Ø = 300 μm	?	60 seconds/ furcation	Parallel alignment	?
II						
Kara et al.[32] Smarty A10, DEKA, Florence, Italy	2.0 W 100 mJ	?	?	90 seconds	?	Yes
III						
Liu et al.[33] Dentlase DLC8, S.L.T., Tokyo, Japan	3.0 W 20 pps = 150 mJ 25 Hz	Contact optical fiber Ø = 400 μm	?	?	Parallel alignment	?
IV						
Miyazaki et al.[15] Opelaser Nd, Yoshida, Tokyo, Japan	2.0 W 20 pps = 100 mJ Total energy dose delivered to each site: 240 J	Contact optical fiber	?	120 seconds/ tooth	Parallel alignment	Yes
V						
Neill and Mellonig[34] PulseMaster 1000, American Dental Technologies	2.0 W 80 mJ Repetition rate: 25 Hz	Contact fiber	?	Average: 120 seconds	Parallel alignment	Upon request
VI						
Noguchi et al.[35] PulseMaster 600LE, American Dental Technologies	2 W 200 mJ 10 pps	Optical fiber Ø = 400μm	?	90 seconds/ tooth	Parallel alignment	No

Table 2. (continued)

Overview of the Selected Studies and Nd:YAG Laser Parameters of Interest

Investigators and Laser Brand	Energy Settings	Tip	Coolant	Contact Time	Fiber Insertion	Anesthesia
VII						
Radvar et al.[36] American dental laser, d.lase-300, Sunrise Technologies, Fremont, California	0.5 W 10 pps = 50 mJ 62.9 J/cm^2 Pulse duration: 150 μm 0.8 W 10 pps = 80 mJ 99.5 J/cm^2 Pulse duration: 150 μm	Contact optical fiber Ø = 320 μm	?	180 seconds/ tooth	Parallel alignment	Yes
VIII						
Sjöström and Friskopp[37] Genius 9 SDL, Mølsgaard Dental, Copenhagen, Denmark	3 W 250 microseconds 60 pps + 7 W 250 microseconds 60 pps	Flexible optical fiber	Yes	Minimum of 60 seconds	In contact with the surface	Upon request

? = unknown/information not given; pps = pulses per second.

that found no difference. Study VII showed a significant difference in PD reduction in favor of SRP. However, three other studies (I, IV, and VIII) did not support this observation. For CAL, study II presented a significant difference in favor of SRP/US. No other differences between groups, with respect to any of the other indices presented, were observed in the selected sufficient articles (I, II, IV, V, VII, and VIII).

DISCUSSION

Most periodontal treatment modalities aim to control disease by reducing the bacterial plaque on the root surface and periodontal tissues to levels compatible with the ability of the host's immune system to control growth. The effectiveness of SRP in the treatment of periodontal disease is universally accepted.[41,42]

Laser energy is capable of ablating and vaporizing residual organic debris, including microbial plaque and probably calculus, and it can disinfect and remove the pocket's sulcular lining.[12-14,33,43,44] Adjunctive therapy, such as laser energy, aimed at reducing or eliminating bacteria may be useful in reducing PD and BOP. The Nd:YAG laser is effective at melting calculus in vivo and in vitro. Total removal of calculus has not been reported in the literature; Tseng and Liew[45] noted that the calculus seemed to separate from the underlying root structure after Nd:YAG laser treatment, which facilitated subsequent removal by scaling. It was suggested that SRP after Nd:YAG laser therapy may be more efficient in removing root deposition, resulting in better periodontal health.[33,43,45-47]

The present review identified eight articles that addressed the clinical outcomes of the Nd:YAG laser in subjects with periodontitis. The data of studies I, II, and IV provided some evidence that the clinical effects of Nd:YAG laser treatment on gingival inflammation and PD are similar to those obtained with conventional SRP/US or US (Tables 5 and 7). In the five articles (I, II, III, V, and VIII) that evaluated the combined treatment of Nd:YAG and supra/subgingival debridement, no evidence was found that using the laser provided additional benefits over those of the conventional approach (ultrasonics and/or hand instrumentation). A gain in CAL is the gold standard when measuring the outcomes of non-surgical periodontal therapy.[13] Only five studies

Table 3.

Quality Assessment of the Studies Analyzed

Quality Criteria	I de Andrade et al.[31]	II Kara et al.[32]	III Liu et al.[33]	IV Miyazaki et al.[15]	V Neill and Mellonig[34]	VI Noguchi et al.[35]	VII Radvar et al.[36]	VIII Sjöström and Friskopp[37]
Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size calculation	?	?	?	?	?	?	?	?
Inclusion/exclusion defined	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Allocation concealment	?	?	?	?	?	?	?	?
Masked to patient	No	No	No	No	No	Yes	Yes	No
Masked to examiner	Yes	No	?	?	Yes	?	?	Yes
Masking during statistical analysis	?	?	?	?	?	?	?	?
Balanced experimental groups	Yes	No	Yes	Yes	No	Yes	Yes	Yes
Reported loss to follow-up	?	?	?	?	?	No	?	Yes
Dropouts (n [%])	0 (0)	0 (0)	0 (0)	0 (0)	?	?	?	1 (3.7)
Treatment identical between groups, except for intervention	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Authors' estimated risk for bias	Moderate	High	High	High	High	High	High	High

? = not specified/unclear.

Table 4.

Overview of the Selected (Nd:YAG laser) Studies for Plaque Index

Number	Study	Index	Intervention	Mean (SD)			Significant Change
				Baseline	End	Difference	
I	de Andrade et al.[31]	Silness and Löe[38]	Nd:YAG + SRP/US	2.11 (0.48)	1.00 (0.61)	−1.11*	Yes
			SRP/US	2.29 (0.77)	1.17 (0.88)	−1.12*	Yes
II	Kara et al.[32]	Silness and Löe[38]	SRP/US + Nd:YAG	1.61 (0.17)	0.17 (0.09)	−1.44*	Yes
			SRP/US	1.47 (0.11)	0.25 (0.13)	−1.22*	Yes
III	Liu et al.[33]	?	Nd:YAG	?	?	?	?
			Nd:YAG + SRP	?	?	?	?
			SRP + Nd:YAG	?	?	?	?
			SRP	?	?	?	?
IV	Miyazaki et al.[15]	Silness and Löe[38]	Nd:YAG	0.36 (0.50)	0.29 (0.47)	−0.07*	No
			US	0.29 (0.48)	0.14 (0.28)	−0.15*	No
VII	Radvar et al.[36]	Silness and Löe[38]	Nd:YAG (50 mJ)	0.80 (0.79*)	0.45 (0.52*)	−0.35 (0.86*)	No
			Nd:YAG (80 mJ)	0.50 (0.52*)	0.40 (0.56*)	−0.10 (0.45*)	No
			SRP	0.65 (0.70*)	0.50 (0.66*)	−0.15 (0.81*)	No

? = unknown.
* Calculated by the authors (Slot et al.).

Table 5.

Overview of the Selected (Nd:YAG laser) Studies for GI

Number	Study	Index	Intervention	Mean (SD)			Significant Change
				Baseline	End	Difference	
I	de Andrade et al.[31]	Löe and Silness[39]	Nd:YAG + SRP/US	2.17 (0.52)	1.11 (0.85)	−1.06*	Yes
			SRP/US	2.17 (0.63)	0.88 (0.69)	−1.29*	Yes
II	Kara et al.[32]	Löe and Silness[39]	SRP/US + Nd:YAG	1.31 (0.09)	0.08 (0.03)	−1.23*	Yes
			SRP/US	1.30 (0.13)	0.11 (0.04)	−1.19*	Yes
III	Liu et al.[33]	Löe and Silness[39]	Nd:YAG	–	–	?	?
			Nd:YAG + SRP	–	–	?	?
			SRP + Nd:YAG	–	–	?	?
			SRP	–	–	?	?
IV	Miyazaki et al.[15]	Löe and Silness[39]	Nd:YAG	1.07 (0.47)	0.50 (0.52)	−0.57 (0.65)	Yes
			US	0.86 (0.53)	0.43 (0.51)	−0.43 (0.76)	Yes
V	Neill and Mellonig[34]	?	Nd:YAG + SRP/US	?	?	?	?
			SRP/US	?	?	?	?
VII	Radvar et al.[36]	Lobene et al.[40]	Nd:YAG (50 mJ)	2.05 (0.56*)	1.80 (0.64*)	−0.25 (0.52*)	No
			Nd:YAG (80 mJ)	1.95 (0.56*)	1.90 (0.52*)	−0.05 (0.56*)	No
			SRP	1.65 (0.70*)	1.15 (0.58*)	−0.50 (0.93*)	No

– = insufficient data presented; ? = unknown.
* Calculated by the authors (Slot et al.).

Table 6.

Overview of the Selected (Nd:YAG laser) Studies for Bleeding Index

Number	Study	Index	Intervention	Mean (SD)			Significant Change
				Baseline	End	Difference	
IV	Miyazaki et al.[15]	BOP	Nd:YAG	1.00 (0.00)	0.57 (0.51)	−0.43 (0.51)	Yes
			US	0.86 (0.36)	0.57 (0.51)	−0.29 (0.47)	Yes
V	Neill and Mellonig[34]	Gingival bleeding index	Nd:YAG + SRP/US	?	?	?	?
			SRP/US	?	?	?	?
VI	Noguchi et al.[35]	BOP	Nd:YAG	73.0%	?	?	?
			Control group	65.6%	?	?	?
VII	Radvar et al.[36]	BOP	Nd:YAG (50 mJ)	–	–	?	No
			Nd:YAG (80 mJ)	–	–	?	No
			SRP	95%	50%	45%	Yes
VIII	Sjöström and Friskopp[37]	Gingival bleeding index	Nd:NCG + SRP	–	–	?	Yes
			SRP	–	–	?	Yes

? = unknown; – = insufficient data presented.

(I, II, IV, V, and VI) reported this clinical parameter, and the majority found no differences among laser treatment, conventional periodontal therapy, or sham treatment. Recently, clinical benefits (PD and CAL) were reported for Nd:YAG laser–assisted removal of pocket epithelium after SRP. These were histologically found to be due to new cementum or the attachment of new connective tissue.[29] However, no statistical analysis was provided to support these findings.

Differences in study design and other factors, such as laser energy settings, may also influence clinical outcomes. Given the same wavelength, different laser parameters yield different levels of energy density for varying periods of time.[13] This produces different

Table 7.

Overview of the Selected (Nd:YAG laser) Studies for PD (mm)

Number	Study	Intervention	Mean (SD)			Significant Change
			Baseline	End	Difference	
I	de Andrade et al.[31]	Nd:YAG + SRP/US	4.9 (1.3)	3.1 (1.1)	−1.8	Yes
		SRP/US	4.8 (1.3)	2.9 (1.0)	−1.9	Yes
II	Kara et al.[32]	SRP/US + Nd:YAG	2.80 (0.17)	1.21 (0.12)	−1.59*	Yes
		SRP/US	2.53 (0.19)	1.27 (0.18)	−1.26*	Yes
III	Liu et al.[33]	Nd:YAG	?	?	?	?
		Nd:YAG + SRP	?	?	?	?
		SRP + Nd:YAG	?	?	?	?
		SRP	?	?	?	?
IV	Miyazaki et al.[15]	Nd:YAG	6.50 (1.09)	5.07 (0.83)	−1.43 (0.94)	Yes
		US	6.86 (2.63)	5.50 (2.06)	−1.36 (1.22)	Yes
V	Neill and Mellonig[34]	Nd:YAG + SRP/US	?	–	−1.7 (1.4)	?
		SRP/US	?	–	−1.7 (1.6)	?
VI	Noguchi et al.[35]	Nd:YAG	4.92 (1.12)	3.35 (1.32)	−1.57	Yes
		Control group	5.8 (1.8)	–	?	No
VII	Radvar et al.[36]	Nd:YAG (50 mJ)	–	–	?	No
		Nd:YAG (80 mJ)	–	–	?	No
		SRP	–	–	?	Yes
VIII	Sjöström and Friskopp[37]	Nd:NCG + SRP	–	–	?	Yes
		SRP	–	–	?	Yes

? = unknown; – = insufficient data presented.
* Calculated by the authors (Slot et al.).

Table 8.

Overview of the Selected (Nd:YAG laser) Studies for CAL (mm)

Number	Study	Intervention	Mean (SD)			Significant Change
			Baseline	End	Difference	
I	de Andrade et al.[31]	Nd:YAG + SRP/US	8.1 (2.1)	7.1 (2.6)	−1.0*	Yes
		SRP/US	7.6 (1.5)	6.0 (1.9)	−1.6*	Yes
II	Kara et al.[32]	SRP/US + Nd:YAG	2.99 (0.34)	2.01 (0.24)	−0.98*	Yes
		SRP/US	2.98 (0.22)	1.87 (0.14)	−1.11*	Yes
IV	Miyazaki et al.[15]	Nd:YAG	7.36 (1.69)	6.86 (1.70)	−0.50 (0.65)	Yes
		US	8.64 (3.16)	8.07 (2.90)	−0.57 (0.85)	Yes
V	Neill and Mellonig[34]	Nd:YAG + SRP/US	?	1.1 (1.9)	?	?
		SRP/US	?	1.0 (1.7)	?	?
VI	Noguchi et al.[35]	Nd:YAG	5.68 (1.55)	4.16 (1.88)	−1.52	Yes
		Control group	6.6 (2.7)	–	?	No

? = unknown.
* Calculated by the authors (Slot et al.).

extents of change in the target tissue. Differences in laser energy settings and contact time may explain the varying degrees of success across the studies in eliminating periodontal pathogens. The eight studies used energy settings ranging from 0.5 to 7.0 W (50 to 200 mJ; Table 2). The degree of vaporization that takes place in the tissue is proportional to the amount of energy absorbed by the tissue. Because energy is a

Table 9.

Overview of the Selected (Nd:YAG laser) Studies for Gingival Recession (mm)

Number	Study	Intervention	Mean (SD)			Significant Change
			Baseline	End	Difference	
I	de Andrade et al.[31]	Nd:YAG + SRP/US	3.3 (1.5)	3.6 (1.6)	+0.3	No
		SRP/US	2.7 (1.3)	3.5 (1.8)	+0.8	No

Table 10.

Descriptives of the Statistical Analyses

Number	Study	Intervention	PI	GI	BI	PD	CAL	GR	Comparison
IV	Miyazaki et al.[15]	Nd:YAG	?	?	?	O	O	■	US
III	Liu et al.[33]	Nd:YAG	?	?	■	?	■	■	SRP
		Nd:YAG + SRP	?	?	■	?	■	■	SRP
		SRP + Nd:YAG	?	?	■	?	■	■	SRP
VII	Radvar et al.[36]	Nd:YAG (50 mJ)	O	O	?	–	■	■	SRP
		Nd:YAG (80 mJ)	O	O	?	–	■	■	SRP
VIII	Sjöström and Friskopp[37]	Nd:NCG + SRP	■	■	O	O	■	■	SRP
II	Kara et al.[32]	SRP/US + Nd:YAG	?	O	■	?	–	■	SRP/US
V	Neill and Mellonig[34]	Nd:YAG + SRP/US	■	+	?	?	O	■	SRP/US
I	de Andrade et al.[31]	Nd:YAG + SRP/US	O	O	■	O	O	O	SRP/US
VI	Noguchi et al.[35]	Nd:YAG	■	■	?	?	?	■	Sham treatment

PI = plaque index; BI = bleeding index; GR = gingival recession; ? = information not given; ■ = no data available; O = no difference; – = negative significant difference; + = positive significant difference.

product of power and duration of exposure (contact time), the penetration depth can be altered by changing the laser's power or the duration of the exposure.[31,48,49] Other studies demonstrated that laser irradiation at a mean power >3 W was effective at reducing bacterial populations.[31] Therefore, low-energy settings may explain the lack of clinical improvement in the study performed by Raffetto.[50] However, that study used a maximum contact time of 180 seconds per tooth, which was higher than most selected studies (Table 2). Higher-energy settings are not always suitable for laser treatment.[35] The number of articles on the action of high-power lasers on periodontal paramenters is modest.

Incomplete removal of microbial residues is another factor that may influence the clinical outcome. This results from incompletely overlapping strokes of the laser probe on root surfaces exposed to periodontitis.[45,46] Therefore, varying tip diameters may account for differences in the outcomes observed in the selected articles. Specifically, a thick laser tip makes deep subgingival application difficult; optical fiber tips, approximately the size of a periodontal probe, may enable the laser tip to access deep periodontal pockets.[50] In all studies, the fiber was moved parallel to the root surface up to the orifice of the pocket. This was done without analgesia in study VI.[35] In one study,[29] the fiber was moved laterally and apically along the pocket wall, eventually arriving close to the base of the pocket.

The use of a laser coolant was mentioned in only one (VIII) of the eight selected articles. There are indications that dry laser irradiation heats up the tissue, and a water-based coolant was effective at reducing these thermal effects.[51] The thermal behavior of laser tips also depends on the type of fiber tips used;[52] with transparent contact probes, a large temperature decrease occurs along the surface of the tip, limiting thermal activation at the very tip of the probe.

In addition to the Nd:YAG laser, the laser types most commonly used in dentistry consist of a variety of wavelengths and are delivered as continuous, pulsed, or running-pulse waveforms.[13] Although the use of lasers in the treatment of periodontitis has been

increasing among practitioners, their efficacy continues to be debated.[53] Three reviews[13,18,19] on lasers in periodontics showed no beneficial effect compared to conventional therapy. This is similar to the conclusions of this systematic review. The consensus report of the Sixth European Workshop on Periodontology[54] stated that there is insufficient evidence to support the clinical application of CO_2, Nd:YAG, Nd:YAP, or other diode lasers because the available clinical studies used these laser applications as adjuncts to mechanical debridement and did not demonstrate significant added clinical value. This conclusion with respect to the Nd:YAG laser was based on the evaluation of only one article.[15] Nevertheless, the present review of eight research studies supports the findings of the consensus report.

CONCLUSIONS

The majority of the studies analyzed showed no beneficial effect of a pulsed Nd:YAG laser compared to conventional therapy (ultrasonics and/or hand instrumentation) in the initial treatment of patients with periodontitis. The pulsed Nd:YAG laser was assessed as monotherapy and as an adjunct to non-surgical periodontal treatment; efficacy was determined by the extent of plaque removal and the reduction of periodontal inflammation. No evidence exists that the Nd:YAG laser is superior to traditional modalities of periodontal therapy.

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