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RESEARCH ARTICLE

APPLICATION OF LASERS IN PERIODONTAL THERAPY: A REVIEW OF LITERATURE WITH PROPOSED CLASSIFICATION

***Dr. Rao Naman Rajeshkumar and Dr. Chandramani B. More**

K. M. Shah Dental College and Hospital, Sumandeep Vidyapeeth University, Pipariya, Vadodara, Gujarat State

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ABSTRACT

Introduction: Controversies relating to the application of lasers in the periodontal therapy have been persisting despite of enormous available literature. This review intends to analyze and clarify the hiding facts about lasers application in periodontal therapy which can develop a new ray of hope in its treatment aspect.

Methods: A comprehensive computer-based search was done using data bases like Medline and Cochrane Library. Manual hand search was also done to search the articles which were not accessible online. All the articles from year 1960 to 2016 were taken in to consideration from which only Randomized control trials, Meta-analysis, Systematic reviews, Case reports, cohort study, case series, review articles were taken in to the consideration. Any other than these with no authenticity like manufacturer's brochure, or any information without references were excluded. After filtering, only 280 articles were found to be useful as topic of interest.

Conclusions: After reviewing the articles, it can be concluded that lasers have definitely given promising results in the treatment of periodontal therapy, but still there are lots of research required for developing Evidence Based Practice of lasers at a clinical setup. More of longitudinal studies with randomized control trials are required for generating the proof and efficacy of lasers in the use for periodontal therapy.

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INTRODUCTION

The expression "LASER" is an ellipsis for "light amplification by stimulated emission of radiation." It denotes to a device that emitslight in spatially coherent and collimated pattern; a laser beam can endure in narrow fashion over a longdistance, and it can also be tightly focused. When directed at tissues, different interactions take place[1]. The absorption, reflection, transmission, and scattering of the laser light vary depending on the wavelength of the laser and the characteristics of the tissue[2]. The lasers systems used for the current practice are namely; Neodymium-doped:Yittrium- Aluminium-Garnet (Nd:YAG), carbon dioxide (CO_2) and semiconductor diode lasers, approved by the United States Food and Drug Administration for soft tissue treatment in oral cavity. The Erbiumdoped: Yittrium-Aluminium-Garnet (Er:YAG) laser was approved in 1997 for hard tissue treatment in dentistry and recent studies and developments reported many positive results. The subject of lasers in periodontics now encompasses a rapidly increasing and significant volume of published literature. Despite the large number of literature over the subject, the current paper aims to present innovative prospects for using lasers in periodontal and to present new perplexing indications of this modern technology for the daily practice in periodontics.

History

Albert Einstein in 1917 stipulated the ideas over stimulated emission radiation. Based on his theory, Maiman developed the first laser prototype in 1960[3] using a crystal of ruby as a medium that emitted a coherent radiation light, when stimulated by energy. In 1961, the first gas and continuously operating laser was described by Javan *et al.* [4] The first application of laser to dental tissue was reported by Goldman *et al.*(1964)[5] and Stern and Sognnaes (1972).[6] However, the current correlation of dentistry with the laser takes its origins from an article published in 1985 by Myers and Myers[7] relating the in vivo excavation of dental caries using a modified ophthalmic Nd:YAG laser. Around 1989, Nd:YAG laser were found potent enough for oral soft tissue

***Corresponding author: Dr. Rao Naman Rajeshkumar**
K. M. Shah Dental College and Hospital, Sumandeep Vidyapeeth University, Pipariya, Vadodara, Gujarat State

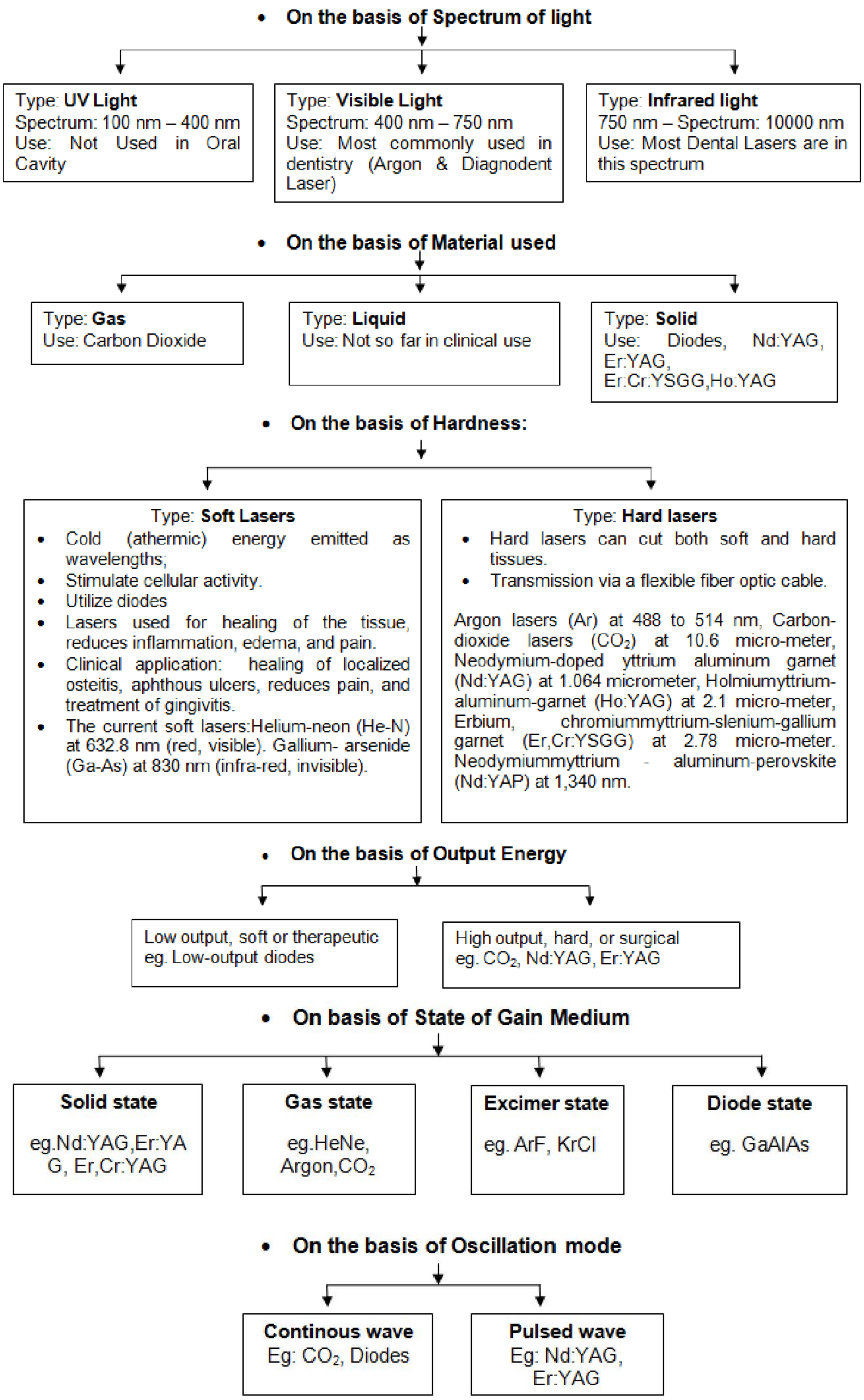
surgeries,[8] that undoubtedly headed to the current relationship between lasers and periodontics.[9,10]

The first Er:YAG laser system was introduced in 1997 with the approval of the Food and Drug Administration for oral use.[11] Nevertheless, with the recent advances and developments, researchers suggest that lasers could be applied for the dental treatments including periodontal, restorative and surgical treatments.

Classification of lasers

Lasers can be classified according[12]

1. On the basis of Spectrum of light
2. On the basis of Material used
3. On the basis of Hardness.
4. On the basis of output energy[11]
5. On basis of state of gain medium
6. On the basis of oscillation mode



Mechanism of action

As lasers are used in vivid medical fields, knowing its mechanism is very important. The laser light is a man-made single photon wave length.It is a type of electromagnetic wave[13],producing heat and converting electromagnetic energy into thermal energy.Laser is lased when an atom is stimulated to emit a photon spontaneously.This stimulated emission generates a very coherent (synchronous waves), monochromatic (a single wavelength), and collimated form (parallel rays) of light that is found nowhere else in nature.[14] The emitted laser has three characteristic features namely: Monochromatic, Coherent, Collimated characteristics. Monochromatic characteristic executes the waves having same frequency and energy. Coherent characteristic executes the waves having certain phase and are related to each other in both relation to its speed and time. Collimated characteristic executes wave which are nearly parallel to each other and the beam divergence is less.[15]

Lasers have property of absorption, reflection, transmission and scattering when targeted over a material.[16] The light energy absorbed by the target tissue in turns converts this light energy to heat and heads towards warming, coagulation, or excision or incision of the target tissue. Waveform is the term that describes the manner of laser power delivered over time, either in continuous pattern or pulsed pattern. Large amount of lasers are delivered in continuous pattern and so large amount of heat is generated, whereas in pulsed wave pattern less amount of heat is generated surrounding the tissue.[17]The characteristic of a laser always depends on its wave-length, which decides its utility.

Materials and Methodology

Various Data bases were explored as a part of search strategy at numerous levels. Data Bases like Medline and Cochrane Library were used. Manual hand search was also done to search the articles which were not accessible online. The articles were taken from year 1960 to 2016 for this review.

The search was done keeping inclusion and exclusion criteria. The criteria's are as follows:

Inclusion criteria:

Only Randomized control trials, Meta-analysis, Systematic reviews, Case reports, cohort study, case series, review articles were taken in to the consideration.

Exclusion criteria:

Any other than above with no authenticity like manufacturer's brochure, or any information without references were excluded. (Non–published data) and articles related to dental implants.

The first search was done with Medline and Cochrane Library using word "Periodontal treatments using lasers". The outcome of this search summed 280 articles which were found to be useful as topic of interest. The divisions of these articles are given in Table 1.

Table 1. Result of combined search from Medline and Cochrane library

S. No.	Article design	Published article	Percentage (%)
1.	Meta-analysis	06	2.14 %
2.	Systematic review	13	4.64 %
3.	Randomized control trial	151	53.92 %
4.	Case report	23	8.21 %
5.	Review article	87	31.07 %
Total articles		280	100 %

Application of lasers

Lasers have a diverse penetration capacity, depending on their wavelength and the type of tissue. For an instance, when applied to soft tissues, Nd: YAG lasers (1064 nm) have a penetration depth of 2–3 mm approximately, compared to CO_2 lasers (10,600 nm), that affect the tissue only superficially (0.1–0.3 mm). In toting, CO_2 lasers have a high absorption from the water.[1] Lasers can be used in a focused beam for excisions and incisions and in an unfocused beam for ablation and coagulation. Some evidences presented by Cobb CM et. al. (2006) suggests that the lasers used as an adjunct to scaling and root planning (SRP) may provide additional benefits.[16] Literature suggests that lasers used in the periodontal treatment are found to be potent for inhibiting bacteremia,[18] excavation of pocket epithelium,efficient subgingival calculus removal[19] and improvement of periodontal regeneration in without damaging the adjoining bone and pulp tissues.[20,21,22]

Application of lasers for bacterial elimination, scaling and calculus ablation

Lasers have shown significant evidence in elimination of bacteria's and calculus. Though lasers have been found potent for bacterial reduction, there is limited evidence showcasing its efficacy in comparison to traditional therapy. Mostly the laser studies done for elimination are in vitro in its design. These in vitro studies cannot mimic the natural environment of oral cavity and thus do not give a significant result which proves that laser superior. Most of these studies have a specific dose/ reaction relationship with bacteria. This interprets that, with increase in power density, it results in more destruction of bacteria's. As per the articles reviewed, many studies showcased that the energy density cannot be measured and thus cannot be reported due to the challenging parameters. These Studies also differs in the procedure/ methodology; some declares its sweeping tip motion and other discusses its static tip exposure to the target surface. To conclude, the angle of irradiation can diverge from 0 to 90 degree, making computation of energy densities nearly impossible. Regardless of these problems, one canstill determine trends in the literature concerning its bactericidaleffects. Out of many studies conducted earlier, one of them being first in vivo study reported by Ito *et al*. (1995) the reduction of pathogenic bacterias using Nd: YAG laser. This study showed remarkable reduction of porphynomonas gingivalis, Aggregatibacter actinomycetemcomitans, Prevotella intermedia. Later, on extraction of teeth 7 days after the treatment showed evidence of recolonization of bacterias on the laser irradiated subgingival root surfaces. [23]Later, a comparison study was conducted between laser therapies of Nd: YAGand SRP, which on a conclusive note reported that both modalities reduced Tannerella forsythensis, porphynomonas gingivalis, and Treponema denticola but incompletely, eliminated Aggregatibacter actinomycetemcomitans. Comparitively laser therapy showed a greater reduction in microbial levels than SRP, although both treatments exhibited microbial rebound approaching baseline levels at 10 weeks post-therapy.[24]The third in vivo studyin year 2002 by Gutknecht N. *et al*. was also a comparative study in which comparison was done between SRP to SRP followed by Nd:YAG laser irradiation at a high density of 124 J/cm^2. The treated pockets were irradiated once per week for continuous 3 weeks. Determination was done at 6 months post treatment for assessing the level of porphynomonas gingivalis, Aggregatibacter actinomycetemcomitans, Prevotella intermedia. In which it was noticed that only the level of porphynomonas gingivalis were found to be significantly reduced in comparison to SRP.[25]

On other hand the in vitro studies using the low power setting of Nd:YAG laser therapy have reported removal of calculus without any damage to Dentin or cementum [26]In comparison there is very few literature relating to the use of diode lasers and interactions with bacteria and dental calculus. In the in vitro study of Harris and Yessik (1997), determined the in vitro ablation threshold for porphynomonas gingivalis for both the 810-nm diode and Nd:YAG lasers to be 48 and 96 J/cm^2, respectively. When this diode laser used adjunct with SRP, it proved to have an additive response in reduction of subgingival bacteria's found in periodontal pockets [27]On contrary,in an in vitro study of Nussbaum Lilge and Mazzulli (2002) it showcased that low level diode laser with 1 J/cm^2 have been found to have stimulatory effect on bacterial growth.[28]

Coffelt *et al*. in 1997[29]conducted an in vitro study in which they demonstrated in vitro ablation of bacteria's with CO_2laser in a defocused mode at an energy density of 11 J/cm^2. It was also determined that the threshold energy density for inducing root damage is 41J/cm^2. Continuing this thought in year 2005, Crespi *et al*[30] concluded that if SRP done followed by a CO_2 laser therapy with density of 2.45 J/cm^2 proved to have no residual bacteria's on root surface. With other lasers with different wavelength studies, there are studies with Er:YAG laser which are at a level of in vitro investigations. Cumulatively these studies did report bactericidal effect with low density of 0.3 J/cm^2,[31]also some study recommended the removal of calculus without damage to the root surface, and root structure removal without any change in pressure or temperature in pulp chamber. [32, 33]Later, contrast to it in the year 2000, Aoki *et al*.[34]in an in vitro study resulted that there is an equal effect on surface of tooth weather with the use of ultrasonic instrumentation orwith Er:YAG laser for removal of calculus from extracted teeth. It was also concluded that slight roughness and microchanges on root surface due to heat.

Eberhard *et al*. [35] in 2003compared laser therapy for removal of calculus with SRP in situ. In this study DNA probe analysis was done by collecting microbial samples both prior to treatment and after the treatment. Digital planimetry was used for measuring residual calculus following the extraction. The study resulted showcased that 68.4% of the root surface was free from calculus in contrast to 94% after SRP. If the laser was used for twice the time as that for SRP, the percentage of root surface devoid of calculus increasedto83.3%. Both these therapy resultedinsimilar lowering of microbes causing pathology.

Later to all these studies, four case control studies were conducted, out of which three focused on usage of Er:YAG laser therapy [36, 37, 38]and one on Nd:YAP laser therapy. All the control groups were SRP in the three studies and in the fourth study surgical flap with debridement. [39]Currently only five clinical trials using diode lasers are published till date, out of which two of them are based on low level laser therapy on experimental model on human gingivitis model that suggested that there is no response of low level laser therapy on plaque, bleeding on probing [40,41]The three remaining studies reported less or not effect on levels of bacterial plaque [42]in comparisons with the control group. Only one article has been reported to have significant effects on clinical parameters which favored the diode laser wavelength.[43]However, as the end resultthese study conducted were having improper controls for the comparison. Proper follow ups were not planned.

Application of lasers for soft tissues in oral cavity

Recently, the use of lasers has achieved a hike with the intra oral soft tissue surgery procedures in comparison to scalpel. It has been evident from the underlying literature including of case reports and case control studies with numerous wavelengths and lasers types primarily; CO_2, Nd: YAG, and the diodes. Surgeries like gingivectomy, gingivoplasty, frenectomy, de-epithilization, degranulation, implant placement, ablation of lesions, biopsies of lesion with any nature, for ulcer treatment, for wound healing, and depigmentation. All the studies over a time have proved collectively potent the advantages of laser over the conventional treatment. The major advantage is the dry field which is achieved with laser and thus better visualization is achieved, following its reduced bacteremia, reduced post-operative pain and swelling, less scarring with quick healing and high patient acceptance.[44]

Though the above mentioned literature showcased about many useful features of lasers, but surprisingly very less data is available on its claim of quick healing and less scaring. The literature suggests that very specific, accurate wavelength and energy density is needed to achieve the mentioned claims. CO_2, diodes and Nd;YAG are the therapies which are explained by various authors in different studies.Comparative study have been carried between CO_2 laser therapy and Nd: YAG therapy in context to wound healing which resulted in to better wound healing or oral mucosa, oropharyngeal and laryngeal mucosa in comparison from Nd: YAG laser therapy. It was also noted that healing was slower than the scalpel induced surgery.[45,46]The quick healing response following the laser induced wound have been reported in literature but not in context to periodontal therapy.[47] Damante *et al* and Masse *et al*have contradicted the quick healing response after periodontal surgery using 670- and 810-nm diode lasers. A positive evidence was reported by Crespi *et al* in which CO_2 laser therapy was used for periodontal surgery in a dog model study.[48] As a cumulative studies over the past studies, it has been reported that laser therapy shows less tendency towards the contraction of scar in comparison to the conventional therapy.[49,50]In a veterinary experimental study model by white *et al*.[51]CO_2, Nd: YAG, Er:YAG, and two diode wavelengths (815 and 980 nm) were used on fresh bovine or porcine jaw. On the basis of histopathology it was concluded that high density laser, long pulsating and high repetition with long interaction times have increased the deteriorated outcome.In this regard, it should be noted that there are various articles published in veterinary and medical journals comparing various laser therapy in comparison to the conventional therapy. Nevertheless, the observations and conclusions of these studies are of limited value to the periodontal surgery. Furthermore, in all these studies the target tissues dermis ormuscle with distant proximity to underlying bone and not the oral mucosa.

Currently, the literature shows only nine published articles with Nd: YAG clinical trials relating to the use of laser therapy for chronic periodontitis. On viewing these articles the results gives an expression of conflicts. [52-59] It showcased that two studies out of these nine trials did not measured periodontitis as an endpoint, three studies resulted less or no difference in periodontitis reduction on comparing laser therapy with SRP and one proving better efficacy of SRP in comparison to lasers. The remaining three trials have showcased the best results of laser for periodontitis in comparison to the historic controls. This suggests that there are conflicts over the laser therapy's efficiency over the conventional methods. and have large standard deviation for mean periodontics reduction which indicates that a great variation in technique is required for best results. After the year 2005 these studies, Nd: YAG laser therapy was combined with minocycline (local delivery) which proved to be useful and showed a significant reduction of periodontitis with reduction of bacteria's, bleeding on probing in comparison to the laser therapy given alone.[56]

There are total six clinical trials that have been in literature on Er: YAG laser therapy for chronic periodontitis is designed better and also showcased better results than other. Out of these six trials, four trials were performed by same investigator which can reason for significant result.[57-65.]These four study conducted by same authors compared the effects of Er: YAG laser therapy alone or with SRP to the control group of SRP.[57-63]The remaining two studies more focused over the intra bony defects.[64,65]Recently a new lasers wavelength has been introduced i.e. Nd:YAP, having a property of absorption coefficient in water approximately is 20 times greater than Nd : YAG laser.

Till date only two researches of clinical trials have been found in literature stating the treatment of chronic periodontitis using lasers. These both research have compared SRP and laser in combine form with SRP alone. The first study reported 1.5mm mean difference in reduction of periodontitis which was 5.5mm initially, also the bleeding on probing reduced markedlywhich favored the use of laser with SRP than SRP alone. The second study intended to measure gingival index, plaque index, BOP, PD, CALs, and the presence of Aa, Pg, Pi, Tf, and Td. The investigator reported no significant difference in any of the measured parameters using laser. Suggesting there is no additional advantage observed using Nd: YAP laser.

Application of lasers for Hard tissues in oral cavity

Lasers have been used at a wide spectrum level in different periodontal surgeries. Discussion about the soft tissue lasers and bacterial removal/ elimination has been already stated. Most common surgeries of bone are osteotomy, osteoplasty, or implants. With evidence of various literatures present till date, bone healing has been stated as the most complex procedure. The temperature 47^0centigrade and 60^0 centigrade has been considered to produce cellular damage and tissue necrosis respectively when exposed to bone.[66]Many lasers have been proved to have a detrimental effect over the bone due to its high intensity of photo thermal effect. Er: YAG and Er,Cr:YSGG are the most excepted lasers for hard tissues laser therapy in periodontics.

Limited literature has been found on the temperature acceptance of bone during the laser therapy on the overlying tissues. One of author's researches is Fontana *et al* [67]in2004,on a rat model using 810 nm diode lasers for the treatment of periodontal pockets, by giving 800 mW laser therapies for continuous 9 seconds; she was reported that there was a rise of 10 to 11^0 centigrade temperature. Only at 600 mW setting there was no cellular damage observed and was so considered as a threshold point. It was also stated that if the exposure was reduced to 3 seconds, it resulted in increased temperature that stayed below the critical threshold

Another study in year 1998 by Spencer P. *et al*, was an in vitro comparison study between CO_2 and Nd: YAG lasers therapies inducing their temperature on underlying hard tissues while irradiating the overlying soft tissues. The energy densities were ranged from 688 J/cm^2 to 1286 J/cm^2;the densities were performed with/ without the surface cooling agents. The result reported that there was an increase in surface temperature from 1.4^0 centigrade to 2.1^0 centigrade using CO_2 laser therapy and 8.0 degree centigrade to 11.1 degree centigrade while using Nd: YAG laser therapy. To conclude it can be confirmed that Nd: YAG laser should be used at a low energy density for short intervals or else there have a risk of irreversible damage of bone/ hard tissues.[68]In studies reporting delayed healing of hard tissue, there were some common observations noted like presence of a char layer (i.e. a residual carbonized layer) on treated surface, presence of inert bone fragments covered with fibrous connective tissues, bone sequestra and fragments surrounded by giant cells. [69,70]

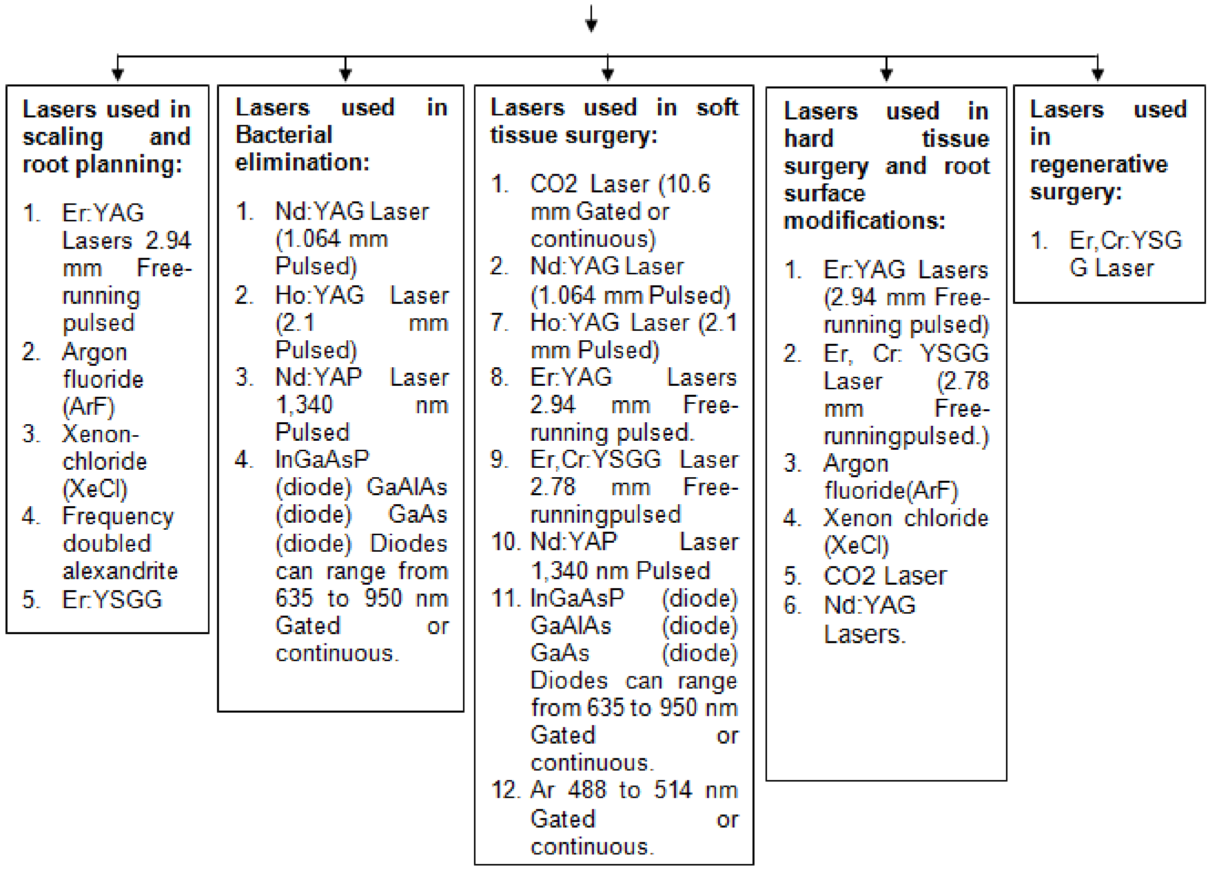
There are total nine studies performed reporting the efficacy and fewer collateral damage of Er:YAG laser. Two of these nine studies have engaged a variety of new techniques to evaluate the Er: YAG laser in rat model study to prepare osteotomy defects. These osteotomy defects were created with Er: YAG laser and was compared to bur and CO_2 laser therapy.[71,72]The study reported that Er: YAG laser, when used at a peak pulse energy of 100 mJ/pulse and 10 Hz will produce well defined infrabony incisions with no evidence of detrimental effect on bone. Contrast to this on using CO_2 laser it resulted to melting of the mineral elements followed by delayed healing

Recently two studies have been highlighted for showcasing the efficacy of Er, Cr:YSGG laser, first kimura *et al* [73]in 2001, an in vitro study evaluated the morphological, atomic and temperature changes in the region of mandibular canine bone. First irradiation with Er,Cr:YSGG laser with power settings of 5 W and 8-Hz pulse repetition for 10 or 30 second durations with continuous air/water surface spray over it. It was observed that maximum temperature increased was 12.6 degree centigrade during the 30 second exposure. **Energy Dispersive X**-Ray Spectroscopy analysis to assess the atomic structure of bone displayed no change in the phosphate and calcium ratio, scanning electron microscope examination for assessing the morphology of bone resulted with no evidence of damaging effect on bone. In year Wang *et al* (2005)in a rabbit model study, have used 80 J/cm^2 energy density laser for creating the osseous perforation of 0.4 mm diameter in maxilla and mandible. They reported a proper and complete normal healing of the wound by 56 days of post treatment.[74]

Laser-induced root surface modifications

Lasers like CO_2, Nd:YAG, Er:YAG, and, to a lesser extent, the diodes have been used majorly for surface modifications of dentin and cementum. [75]Majorly wavelengths have to be taken in to consideration for using lasers over the root surface to avoid the damage to root and effects to pulp. CO_2 laser was studied first for the root surface modification. It was used at a very low power of 4 W, result was not encouraging as it reported in charring and melting of the root surface. On analysis, cytotoxic chemical residues like cyanate and cyanamide was found.[76]Many recent studies on CO_2 laser on its biocompatibility, when used at a low density have an increased in vitro attachment of fibroblast to laser treated roots.[77,38]Whereas contrasting to it, Fayad *et al* (2004),[79] have reported lack of attachment of fibroblast to the treated surface in comparison to SRP or chemical treatment. In the study of Gopin *et al* (1997),[80] in an animal model, comparison between CO_2 laser therapy and SRP was done for reattachment of mucopariosteal flap on the treated root. The observation of the study stated that CO_2 laser treated tooth did not show any attachment, whereas SRP treated root showed the reattachment. Charring and cracking of the root surface is a very common observation when treated with CO_2 laser at a power setting of 4 W, when delivered in a continuous waveform. However when this power is defocused and pulsed at a low power, the damaged reported is less and have been also found effective in terminating smear layers. [81,82]though these was found to be efficient for some therapy, latter the result suggested its restricted role in subgingival periodontal treatment. After year 1997, Nd: YAG laser were experimented for the root surface modification. In the study of Israel *et al* [83], comparison was done between all the lasers namely, CO2 laser, Nd:YAG laser and Er: YAG lasers, the study reported that the use of Nd: YAG laser have been showing morphological changes like cavitation, char layers, crazing, melting, directly associated with the energy density irrespective of usage of coolant.

Figure 1: Proposed classification of Laser application for Periodontal therapy, by Rao Naman and More Chandramani



A current study by Chen *et al.* (2005), [84] in a cell line study of human periodontal ligament fibroblast were irradiated by Nd: YAG laser at a low energy density, the study reported detrimental result by showing significant decrease in cellular viability, evidence of mineralization of necrotic cells were also observed post treatment. Two studies [85, 86]in their in vitro studies have demonstrated efficient removal of smear layer when low energy Nd: YAG laser used with a defocused beam without causing any collateral damage to the underlying hard and soft connective tissues. As high destruction in context to water and hydroxyapatite crystals, Er: YAG laser therapies have been experimented for better root surface modification without any contralateral damage to surroundings. The wavelength used in different studies has shown the effective removal of smear layer, [83,87]cementum,[88,89] Dental calculus,[90 to 93.] These lasers at a low level have shown promising results with very negligible damage to the tissue with producing smooth root surface.[94,95]Studies conducted by Parker S. (2004)[96], Flax H (2004, 2005)[97], [98] and Adams TC *et al* (2004)[99] have reported the efiicacy of Er,Cr: YSGG lasers in crown lengthening with flapless procedureand have also found that they are superior to other lasers.

Conclusion

After reviewing these articles, it can be concluded that lasers have definitely given promising results in the treatment of periodontal therapy, but still there are lots of research required for developing Evidence Based Practice of lasers at a clinical setup. More of the clinical trials and longitudinal studies are required at a human model level for generalizing the laser therapy in periodontology. As the lasers have been a costly affair with more time required for its procedure, multicenter collaborative studies shall be conducted so to provide relevant result. Very few studies over application of lasers on chronic generalized periodontitis have been conducted, thus furthermore studies are required for its confirmatory usage. Diode in particulars needs to be improved with more clinical trials to get its accurate wavelength so that less collateral damage takes place. The lasers have shown less evidence on its efficacy for periodontal therapy due improper usage over tissues irrespective of hard or soft tissues. Both Hard and soft tissues need different lasers with particular wavelength and its density. Nevertheless even on the basis of treatment modalities the laser with its particular wavelength and densities should be used for achieving beneficial results. Thus here after reviewing these literatures, authorsproposes the classification of lasers (Figure 1) on the basis of its application in periodontal therapy which will be helpful to Periodontists, Private practitioner and Researchersfor the best of its use for exploring much better results on periodontal therapy and thereby giving a better quality of life to the patients.

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