Clinical Efficacy of Laser Therapy in Peri-Implantitis: A Review

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Abstract:- Dental Implantology has evolved into a therapeutic option with an incredibly predictable outcome. It is used extensively in regular clinical practice and provides an effective treatment alternative for treating a wide range of patients. Pathological diseases in the tissues around dental implants, such as "mucositis" and "peri-implantitis," can cause osseointegration problems over time. Despite the fact that a variety of treatments have been recommended for peri-implant care, lasers have cemented themselves as the gold standard for treating peri-implantitis and lowering bacterial counts in the afflicted regions.

Keywords:- *Lasers, peri implantitis, osseointegration, Er: YAG, Diode.*

I. INTRODUCTION

Dental implantology has become a treatment option harnessing a remarkably predictable outcome. It forms up a large part of the daily clinical practice and offers a successful therapeutic option available for treating patients who are partly or completely edentulous.[1]Despite their technical development taking place at the beginning of 1960, when Branemarck's group introduced fresh and ground-breaking ideas based on their recognition of the biological phenomena that took place at the interface between bone and implant, implant-supported prosthetics in dentistry only eventually started to be implemented. Osseointegration is the term used to refer to the development of a rigid and functional bond between bone and an implant fixture when both are being loaded by a prosthetic device without the intervention of connective tissue. Even yet, osseointegration errors may result from pathological conditions to the tissues around dental implants over time. These pathological conditions, which are referred to as "mucositis" and "peri-implantitis" (PI) depending on whether the inflammatory processes only affect the marginal gingiva or the deep peri-implant tissues, have risen in recent years in direct proportion to the use of dental implants.[2]

II. PERI- IMPLATITIS AND IMPLANT FAILURE

A complicated concept known as peri-implantitis (PI) affects the tissues surrounding an implant that is continually performing its intended function. An inflammatory cascade that would initially affect the superficial peri-implant soft tissues (mucositis) and then progress into the deep layers, with a loss of implant support bone that can be clinically and radiologically highlighted, could be brought on by a disadvantageous balance between pathogenic bacterial load and host response (peri-implantitis).[3]

Risk factors that increase a person's probability of developing peri implantitis, which shares many symptoms with periodontitis, include prior periodontal disease, poor dental hygiene, smoking, hereditary factors, diabetes, leftover cement, and occlusal overload.[4]The primary cause of peri-implantitis is assumed to be microorganisms residing on the implant surface. These bacteria establish a biofilm that prevents bone cells from reattaching to the implant surface and triggers a detrimental inflammatory cascade in the host.[5]

Clinical evidence for PI includes bleeding post probing in the peri implant area, an increase in probing depth, and marginal bone loss.[6]According to a review paper written by Mombelli and his colleague, the prevalence of PI was estimated at 10% of implants and 20% of patients five to ten years following implant loading.[7]

III. TREATMENT APPROACHES

Even though a number of therapies have been indicated for peri-implant care, the literature has not yet documented a consensus on the approach that is the most dependable, repeatable, and efficient. In order to successfully treat PI, it is vital to decontaminate the implant components in addition to removing any inflamed soft tissue from the peri-implant region.[8]Various surgical and non-surgical therapies are aimed in eliminating bacterial biofilms formed on dental implants for example mechanical debridement, disinfection with chemotherapeutic agents, smoothing implant surface and laser therapy, which is the new treatment modality employed.[9]

With carbon, plastic, titanium, ultrasonic scaling, or powder air abrasion, mechanical debridement can be accomplished.[10]Tetracycline fibres, chlorhexidine digluconate, and minocycline microspheres all appear to possess powerful antibacterial properties. Due to resistant bacterial strains, restricted access to the inflamed region, and pharmacologic constraints like inadequate antibacterial action or insufficient medication dose, the efficacy of mechanical or chemical modalities appears to be constrained.[11]Additionally, mechanical techniques including metallic curettes, ultrasonic metal tip scalers, and air powder abrasion may cause an implant's surface to become rougher, which in turn promotes bacterial colonisation and biofilm development.[12]

Recently, a discernible trend has compelled scientists to use lasers to clean inflammatory periimplant tissue. Small portions of the implant surface that mechanical techniques are unable to reach can be effectively irradiated by lasers. The selective calculus removal, antibacterial, and hemostatic actions of lasers all contribute to improved clinical results.[13]The effectiveness of Er:YAG (Erbium-Doped Yttrium Aluminum Garnet), CO_2 (Carbon Dioxide Laser), and Diode lasers in the high or even total removal of bacteria-loaded titanium discs has been demonstrated in in vitro models.[14]Additionally, microscopic analyses have confirmed that the titanium surface is not disturbed when these lasers are applied correctly.[15,16]

Practitioners must make a number of choices when thinking about using lasers to treat peri implantitis. There are several different types of lasers, such as Er:YAG, CO2, Diode, Er,Cr:YSGG (Erbium, Chromium doped Yttrium Scandium Gallium Garnet), and diode lasers (810 nm, 940 nm, and 980 nm) (NeodymiumDoped Yttrium Aluminium Garnet). It could be necessary to combine laser therapy with additional forms of treatment.[17]Thus the aim of this current review is to highlight the use of lasers in the treatment of peri implantitis and to review the efficacy of different lasers in the treatment of the same.

IV. ER:YAG LASER FOR TREATMENT OF HUMAN PERIIMPLANTITIS

Under the proper irradiation parameters, it has been demonstrated that utilising the Er:YAG laser, contaminated abutments may be successfully cleaned of calculus and plaque. This is accomplished while causing any surface damage to the titanium and without greatly raising the temperature. It has been proven that using the Er:YAG laser, contaminated abutments may be effectively cleared of calculus and plaque under the right irradiation conditions without titanium surface deterioration or considerable temperature rise.[18]

In light of the findings of earlier research and the benefits of the Er:YAG laser in periodontal treatment, such as its superior tissue ablation,[19]with high bactericidal,[20] and detoxification effects,[21] the potential of Er:YAG laser application for the treatment of peri-implantitis would be expected.[22]When paired with local antibiotics, Er:YAG may lessen the clinical indications of inflammation when treating peri-implantitis without surgery, according to studies that compared it to curettes and chlohexidine.[23]A systematic review of laser treatment conducted by Kotsovilis et al., who came to the conclusion that Er:YAG combined with mechanical debridement may be utilised for peri-implantitis.[24]Three different laser types were reviewed by Kotsakis et al., some of which were applied as a peri-implantitis treatment adjunct, but no conclusion was drawn as to which laser type was better than the others.[25]Mailoa et al. reported on the use of two types of lasers (Er:YAG and CO2) to treat peri-implantitis in both people and animals, but other laser types were left out of the review.[26]

The impact of the Er:YAG laser on peri-implantitis has been shown in papers by Schwarz et al. Following therapy, the patients came back six months later. Both the use of Er:YAG and plastic tools resulted in appreciable advancements in the healing process surrounding the implant; however, the use of Er:YAG led to a higher decrease in BoP than the use of plastic instruments alone.[27]In a different population and using the same research methodology (RCT) of test and control, Schwarz et al. conducted another study in 2006. The patients were followed for up to 12 months. When compared to plastic tools and chlorhexidine, Er:YAG significantly reduced BoP at 6 months, but at 12 months after treatment, there was no discernible change in healing.[28]

Using a test group (Er:YAG) and a control group as their comparison, Renvert et al. published a 6-month follow-up research (subgingival airborne glycine powder polishing). Both at the beginning and six months, they measured the BoP and pocket depth. Both treatment modalities resulted in comparable recovery surrounding the implants, they discovered.[29]Following the usage of the Er:YAG laser for six months, Badran et al. reported on a single implant that had been identified with peri-implantitis. After undergoing nonsurgical treatment, the patient had surgery. The findings revealed no BoP and a decrease in probing depth (2 to 5 mm), but an increase in gingival recession (1 to 2 mm). The process of bone healing surrounding the implant was effective.[30]Using the Er:YAG laser alone to treat peri-implantitis without surgical intervention was shown to be ineffective in one of the studies included in a comprehensive review by Schwarz et al.[31]

V. ND:YAG LASER FOR TREATMENT OF HUMAN PERIIMPLANTITIS

Initially, the neodymium-doped yttrium-aluminum-garnet (Nd:YAG) laser (Nd:Y3Al5O12) was advised against using it near implants because it caused morphologic changes to the titanium surface, such as melting, cracking, and cratering. Microorganism growth in those voids or porosities may be facilitated by changes in the surface topography.[32,33]

On the other hand, Giannini et al. observed that the Nd:YAG laser, when applied in vitro at low pulse energy, had a bactericidal effect without causing any harm to the titanium surface.[34]No human studies have yet evaluated the effect of Nd:YAG laser therapy on peri-implantitis.

VI. CO_2LASER FOR TREATMENT OF HUMAN PERIIMPLANTITIS

A gas-active medium laser, the CO_2 laser uses an electrical discharge current to pump a gaseous mixture including CO_2 molecules inside a sealed tube. The versatility and accuracy needed for soft tissue surgical operations are provided by the CO_2 laser's capacity to deliver the requisite power in continuous and gated modes with focused or nonfocused hand-pieces. This wavelength, which is nearly 1000 times more effective than erbium, has the greatest hydroxyapatite absorption of any dental laser. To protect tooth structure from the incident laser beam at the soft tissue surgery site, it is necessary.[35]

Patients in a study by Deppe et al. were followed for 5 years. Results obtained four months after treatment indicated that using a CO_2 laser in conjunction with removing soft tissue may have sped up the healing process. The CO_2 laser and airborne-powder abrasion (Prophy-Jet, Dentsply) did not vary in the long-term results for implant decontamination treatment.[36]The CO_2 laser, in combination with augmentative approaches, may be a successful treatment option for peri-implantitis, according to the findings of a case series research by Romanos et al. that lasted 27 months.[37]

Based on preliminary clinical results, Romanos et al. investigations from 2008 and 2009 concluded that CO_2 laser was a useful technique for implant surface cleansing. In Romanos et al 2008's trial, BOP and PPD were greatly decreased, and an adequate rate of bone fill was attained; nevertheless, the breadth of keratinized mucosa didn't increase appreciably. It was unclear whether there had been any change in the pattern of healing because they had only compared the indices at baseline and final with a follow-up period of 27±17 months. Romano's 2009 study did not contain any soft tissue measurements, and evaluation was entirely based on radiographic signs of healing.[38,39]

VII. Er,Cr:YSGGLASER FOR TREATMENT OF HUMAN PERIIMPLANTITIS

With a wavelength of 2.78 m, Er,Cr:YSGG lasers belong to the family of erbium lasers and exhibit very shallow tissue penetration, offering little thermal danger to deeper tissues. Er,Cr:high YSGG's absorption in water has been linked to the morphological surface modifications it promotes. In comparison to standard treatment protocol, the use of the Er,Cr:YSGG laser as an adjuvant has reportedly been found to be more successful in reducing bacterial growth.[40]

A low-energy Er:YAG laser appears to have favourable effects when used to clean the implant surfaces.[41]A single implant was monitored for 18 months' time period in a study published by Azzeh in 2008. Using Er,Cr:YSGG, the implant surface was decontaminated at the time of surgery followed by anorganic bovine bone grafting in the defect location, and a resorbable membrane was placed over the top. All probing depths were 2 mm 18 months after surgery, and the implant's surrounding osseous tissue was found to be regenerating.[42]

VIII. DIODE LASER FOR TREATMENT OF HUMAN PERI IMPLANTITIS

Diode lasers are produced at a variety of wavelengths, including 810 nm, 940 nm, and 980 nm. They can be used in gated pulse mode or continuous wave mode, which emits energy as a steady beam (energy emitted as a constant but interrupted beam).[43]Gallium-aluminum-arsenide (810 nm) and indium-gallium-arsenide (InGaAs) lasers are the two most often employed wavelengths in the treatment of peri-implantitis (980 nm).[44]Since the peak water absorption will help prevent a temperature increase at the implant surface, the use of a 980-nm diode laser has been demonstrated to be more favourable around dental implants, even at higher power levels.[45]The bactericidal impact of this wavelength on implant surfaces has also been demonstrated in tests without altering the pattern of the implant surface.[46,47]

The diode laser also stimulates fibroblasts and osteoblasts, which leads to an increase in RNA messenger synthesis and considerable collagen creation during periodontal tissue repair, potentially making it a viable alternative strategy for the treatment of peri-implantitis.[48]

In one in vitro study, Stübinger et al. discovered that the removal of bacteria that cause peri-implantitis, such as Streptococcus sanguinis and Porphyromansgingivalis, was effective regardless of the implant material when using a diode laser with an 810-nm wavelength, 3 W for 10 s, and a 200-m fibre tip.[47]

Diode laser was employed by Schar et al. and Bassetti et al. using the exact same protocols, including laser irradiation in conjunction with Phenothiazine chloride, 3 minutes after hand curettage, air powder abrasion, and irrigation with hydrogen peroxide. One week after the initial treatment, adjunctive PDT (Photodynamic Therapy) was performed. In both investigations, the modified plaque index was recorded, and at the final treatment checkups, it was significantly lower (6 and 12 months respectively). The laser group had no plaque at month 6 according to Schar et al.[49,50]

IX. DISCUSSION

The major objectives of treating peri-implantitis are to eradicate the inflammatory lesion, stop the disease's development, and preserve function with healthy peri-implant tissues. The elimination of etiologic elements such adherent plaque, bacterial deposits, and diseased connective tissue inside intrabony defects around the implants have all been recognised as crucial to achieving the desired outcome. However, due to their propensity for damaging the titanium surfaces of implants, conventional mechanical instruments like steel curets or ultrasonic scalers are not entirely suitable for the removal of granulation tissue and implant surface debridement. This could obstruct the process of bone healing.As a result, mechanical tools like plastic curets and carbon fibre curettes are typically used for implant debridement.[51]

The thorough debridement of the bone defect and the contaminated implant surface, however, appears to be inefficient using these procedures, and mechanical debridement is difficult and time-consuming.Because of this, mechanical debridement in the case of peri-implantitis has made it much harder to completely remove pollutants like bacteria and their byproducts and soft tissue cells from the rough surface, and the residual plaque biofilm may hinder the healing of the peri-implant tissues.[52]Novel treatment techniques utilising lasers have received a lot of interest recently. Lasers have been used in periimplant therapy as an additional or alternative treatment and are anticipated to alleviate the issues and challenges of the traditional mechanical treatment. According to the results of the current review, only CO2, DIODE, and Er:YAG lasers were utilised to effectively treat peri-implantitis lesions. This could be explained by the fact that these two kinds of lasers did not considerably raise the body temperature of the implants while they were being used.[53]

An fascinating laser that has not been discussed in any research is the neodymium: yttrium-aluminum-garnet (Nd:YAG) laser; one justification for this is that titanium is abraded by Nd:YAG lasers independent of output energy. The use of Nd:YAG for the treatment of periimplantitis might not be advised due to the high temperature and titanium's propensity to melt.[33]Additionally, CO_2 and Er:YAG lasers were the only ones to be described as having a variety of bactericidal effects on textured implant surfaces.[54]All periimplantitis patients in human clinical studies who had surgical or non-surgical laser treatment for their condition exhibited a decrease in PD and BOP. The laser group's lower PD and BOP scores might be attributed to their strong bactericidal effects.[55,56]

The elimination of lipopolysaccharides by laser radiation and the antibacterial activities against periodontopathic bacteria were also documented in various research.[57] According to a prior study, employing CO2 lasers along with bone grafting material resulted in a 40% increase in radiographic bone fill when compared to the control group.[58]

X. CONCLUSION

Nowadays, laser therapies offer a novel treatment approach for peri implantitits and they are being integrated along with conventional mechanical therapies.Er:YAG , Diode and CO_2 Lasers have demonstrated better results as compared to Nd:YAG Laser. A significant reduction in PPD and BOP was seen along with high bactericidal effects on the implant surface. The results validate the efficacy of the laser irradiation in high decontamination of anaerobic bacteria and improving bone regeneration, therefore making the use of lasersan essential part of the treatment protocol for peri- implantitis.

REFERENCES

[1.] Sánchez-Gárces MA, Gay-Escoda C. Periimplantitis. Med Oral Patol Oral Cir Bucal. 2004; 63:69-74.
[2.] López-Cerero L. Infeccionesrelacionadas con losimplantesdentarios [Dental implant-related infections]. EnfermInfeccMicrobiol Clin. 2008;26:589-92.
[3.] Algraffee H, Borumandi F, Cascarini L. Peri-implantitis. Br J Oral Maxillofac Surg. 2012;50:689-94.
[4.] Lindhe J, Meyle J. Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. J Clin Periodontol. 2008;35:282-5.
[5.] Salmeron S, Rezende ML, Consolaro A, Sant'Ana AC, Damante CA, Greghi SL, et al. Laser therapy as an effective method for implant surface decontamination: A histomorphometric study in rats. J Periodontol. 2013;84:641-9.
[6.] Renvert S, Hirooka H, Polyzois I, Kelekis-Cholakis A, Wang HL. Working Group 3. Diagnosis and non-surgical treatment of peri-implant diseases and maintenance care of patients with dental implants - Consensus report of working group 3. Int Dent J. 2019;69:12-17.
[7.] Mombelli A, Müller N, Cionca N. The epidemiology of peri-implantitis. Clin Oral Implants Res. 2012;23:67-76.
[8.] Esposito M, Grusovin MG, Kakisis I, Coulthard P, Worthington HV. Interventions for replacing missing teeth: treatment of perimplantitis. Cochrane Database Syst Rev. 2008;16:CD004970.
[9.] Ntrouka VI, Slot DE, Louropoulou A, Van der Weijden F. The effect of chemotherapeutic agents on contaminated titanium surfaces: a systematic review. Clin Oral Implants Res. 2011;22:681-90.
[10.] Persson GR, Salvi GE, Heitz-Mayfield LJ, Lang NP. Antimicrobial therapy using a local drug delivery system (Arestin) in the treatment of peri-implantitis. I: Microbiological outcomes. Clin Oral Implants Res. 2006;17:386-93.
[11.] Peters N, Tawse-Smith A, Leichter J, Tompkins G. Laser therapy: the future of peri-implantitis management. Braz J Periodontol. 2012;22:23-9.
[12.] Gosau M, Hahnel S, Schwarz F, Gerlach T, Reichert TE, Bürgers R. Effect of six different peri-implantitis disinfection methods on in vivo human oral biofilm. Clin Oral Implants Res. 2010;21:866-72.
[13.] Matsuyama T, Aoki A, Oda S, Yoneyama T, Ishikawa I. Effects of the Er:YAG laser irradiation on titanium implant materials and contaminated implant abutment surfaces. J Clin Laser Med Surg. 2003;21:7-17.
[14.] Tosun E, Tasar F, Strauss R, Kıvanc DG, Ungor C. Comparative evaluation of antimicrobial effects of Er:YAG, diode, and CO_2 lasers on titanium discs: an experimental study. J Oral Maxillofac Surg. 2012;70:1064-9.
[15.] Stubinger S, Etter C, Miskiewicz M, Homann F, Saldamli B, Wieland M, Sader R. Surface alterations of polished and sandblasted and acid-etched titanium implants after Er:YAG, carbon dioxide, and diode laser irradiation. Int J Oral Maxillofac Implants. 2010 ;25:104-11.
[16.] Park JH, Heo SJ, Koak JY, Kim SK, Han CH, Lee JH. Effects of laser irradiation on machined and anodized titanium disks. Int J Oral Maxillofac Implants. 2012;27:265-72.
[17.] Ashnagar S, Nowzari H, Nokhbatolfoghahaei H, Yaghoub Zadeh B, Chiniforush N, Choukhachi Zadeh N. Laser treatment of peri-implantitis: a literature review. J Lasers Med Sci. 2014;5:153-62.
[18.] Takasaki AA, Aoki A, Mizutani K, Kikuchi S, Oda S, Ishikawa I. Er:YAG laser therapy for peri-implant infection: a histological study. Lasers Med Sci. 2007;22:143-57.
[19.] Mizutani K, Aoki A, Takasaki AA, Kinoshita A, Hayashi C, Oda S, Ishikawa I. Periodontal tissue healing following flap surgery using an Er:YAG laser in dogs. Lasers Surg Med. 2006;38:314-24.
[20.] Ando Y, Aoki A, Watanabe H, Ishikawa I. Bactericidal effect of erbium YAG laser on periodontopathic bacteria. Lasers Surg Med. 1996;19:190-200.
[21.] Yamaguchi H, Kobayashi K, Osada R, Sakuraba E, Nomura T, Arai T, Nakamura J. Effects of irradiation

of an erbium:YAG laser on root surfaces. J Periodontol. 1997;68:1151-5.
[22.] Aoki A, Sasaki KM, Watanabe H, Ishikawa I. Lasers in nonsurgical periodontal therapy. Periodontol 2000. 2004;36:59-97.
[23.] Muthukuru M, Zainvi A, Esplugues EO, Flemmig TF. Non-surgical therapy for the management of peri-implantitis: a systematic review. Clin Oral Implants Res. 2012;23:77-83.
[24.] Kotsovilis S, Karoussis IK, Trianti M, Fourmousis I. Therapy of peri-implantitis: a systematic review. J Clin Periodontol. 2008;35:621-9.
[25.] Kotsakis GA, Konstantinidis I, Karoussis IK, Ma X, Chu H. Systematic review and meta-analysis of the effect of various laser wavelengths in the treatment of peri-implantitis. J Periodontol. 2014;85:1203-13.
[26.] Mailoa J, Lin GH, Chan HL, MacEachern M, Wang HL. Clinical outcomes of using lasers for peri-implantitis surface detoxification: a systematic review and meta-analysis. J Periodontol. 2014;85:1194-202.
[27.] Renvert S, Lindahl C, RoosJansåker AM, Persson GR. Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: a randomized clinical trial. J Clin Periodontol. 2011;38:65-73.
[28.] Schwarz F, Bieling K, Bonsmann M, Latz T, Becker J. Nonsurgical treatment of moderate and advanced periimplantitis lesions: a controlled clinical study. Clin Oral Investig. 2006;10:279-88.
[29.] Schwarz F, Sculean A, Rothamel D, Schwenzer K, Georg T, Becker J. Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. Clin Oral Implants Res. 2005;16:44-52.
[30.] Badran Z, Bories C, Struillou X, Saffarzadeh A, Verner C, Soueidan A. Er:YAG laser in the clinical management of severe peri-implantitis: a case report. J Oral Implantol. 2011;37:212-7.
[31.] Schwarz F, Bieling K, Nuesry E, Sculean A, Becker J. Clinical and histological healing pattern of peri-implantitis lesions following non-surgical treatment with an Er:YAG laser. Lasers Surg Med. 2006;38:663-71.
[32.] Kreisler M, Kohnen W, Christoffers AB, Götz H, Jansen B, Duschner H, d'Hoedt B. In vitro evaluation of the biocompatibility of contaminated implant surfaces treated with an Er : YAG laser and an air powder system. Clin Oral Implants Res. 2005;16:36-43.
[33.] Romanos GE, Everts H, Nentwig GH. Effects of diode and Nd:YAG laser irradiation on titanium discs: a scanning electron microscope examination. J Periodontol. 2000;71:810-5.
[34.] Giannini R, Vassalli M, Chellini F, Polidori L, Dei R, Giannelli M. Neodymium:yttrium aluminum garnet laser irradiation with low pulse energy: a potential tool for the treatment of peri-implant disease. Clin Oral Implants Res. 2006;17:638-43.
[35.] Garg N, Verma S, Chadha M, Rastogi P. Use of carbon dioxide laser in oral soft tissue procedures. Natl J Maxillofac Surg. 2015;6:84-88.
[36.] Deppe H, Horch HH, Neff A. Conventional versus CO2 laser-assisted treatment of peri-implant defects with the concomitant use of purephase beta-tricalcium phosphate: A 5-year clinical report. Int J Oral Maxillofac Implants 2007;22:79–86.
[37.] Romanos GE, Nentwig GH. Regenerative therapy of deep peri-implant infrabony defects after CO2 laser implant surface decontamination. Int J Periodontics Restorative Dent 2008;28:245–55.
[38.] Hürzeler MB, Quinones CR, Schüpbach P, Morrison EC, Caffesse RG. Treatment of periimplantitis using guided bone regeneration and bone grafts, alone or in combination, in beagle dogs. Part 2: Histologic findings. Int J Oral Maxillofac 1997;12: 168–175.
[39.] Romanos G, Ko H-H, Froum S, Tarnow D. The use of CO2 laser in the treatment of peri-implantitis. Photomedicine and laser surgery. 2009;27:381-6.
[40.] Dereci Ö, Hatipoğlu M, Sindel A, Tozoğlu S, Üstün K. The efficacy of Er,Cr:YSGG laser supported periodontal therapy on the reduction of peridodontal disease related oral malodor: a randomized clinical study. Head Face Med. 2016;12:20.
[41.] Chegeni E, España-Tost A, Figueiredo R, Valmaseda-Castellón E, Arnabat-Domínguez J. Effect of an Er,Cr:YSGG Laser on the Surface of Implants: A Descriptive Comparative Study of 3 Different Tips and Pulse Energies. Dent J (Basel). 2020;8:109.
[42.] Azzeh MM. Er,Cr:YSGG laser-assisted surgical treatment of peri-implantitis with 1-year reentry and 18-month follow-up. J Periodontol2008;79:2000–5.
[43.] Stubinger S, Etter C, Miskiewicz M, Homann F, Saldamli B, Wieland M, Sader R. Surface alterations of polished and sandblasted and acid-etched titanium implants after Er:YAG, carbon dioxide, and diode laser irradiation. Int J Oral Maxillofac Implants. 2010;25:104-11.
[44.] Schwarz F, Aoki A, Sculean A, Becker J. The impact of laser application on periodontal and peri-implant wound healing. Periodontol 2000. 2009;51:79-108.
[45.] Azma E, Safavi N. Diode laser application in soft tissue oral surgery. J Lasers Med Sci. 2013;4:206-11.
[46.] Natto ZS, Aladmawy M, Levi PA Jr, Wang HL. Comparison of the efficacy of different types of lasers for the treatment of peri-implantitis: a systematic review. Int J Oral Maxillofac Implants. 2015;30:338-45.
[47.] Hauser-Gerspach I, Stübinger S, Meyer J. Bactericidal effects of different laser systems on bacteria adhered to dental implant surfaces: an in vitro study comparing zirconia with titanium. Clin Oral Implants Res. 2010;21:277-83.
[48.] Roncati M, Lucchese A, Carinci F. Non-surgical treatment of peri-implantitis with the adjunctive use of an 810-nm diode laser. J Indian Soc Periodontol. 2013 Nov;17:812-5.
[49.] Schär D, Ramseier CA, Eick S, Arweiler NB, Sculean A, Salvi GE. Anti-infective therapy of peri-implantitis with adjunctive local drug delivery or photodynamic therapy: six-month outcomes of a prospective randomized clinical trial. Clinical oral implants research. 2013;24:104-10.

[50.] Bassetti M, Schär D, Wicki B, Eick S, Ramseier CA, Arweiler NB, Sculean A, Salvi GE. Anti-infective therapy of peri-implantitis with adjunctive local drug delivery or photodynamic therapy: 12-month outcomes of a randomized controlled clinical trial. Clin Oral Implants Res. 2014;25:279-287.
[51.] Schwarz F, Sculean A, Rothamel D, Schwenzer K, Georg T, Becker J. Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. Clin Oral Implants Res. 2005;16:44-52.
[52.] Schwarz F, Sculean A, Romanos G, Herten M, Horn N, Scherbaum W, Becker J. Influence of different treatment approaches on the removal of early plaque biofilms and the viability of SAOS2 osteoblasts grown on titanium implants. Clin Oral Investig. 2005;9:111-7.
[53.] Kreisler M, Kohnen W, Marinello C, et al. Bactericidal effect of the Er:YAG laser on dental implant surfaces: An in vitro study. J Periodontol 2002;73: 1292-98.
[54.] Kato T, Kusakari H, Hoshino E. Bactericidal efficacy of carbon dioxide laser against bacteria-contaminated titanium implant and subsequent cellular adhesion to irradiated area. Lasers Surg Med 1998;23:299-309.
[55.] Kreisler M, Kohnen W, Marinello C, et al. Bactericidal effect of the Er:YAG laser on dental implant surfaces: An in vitro study. J Periodontol 2002;73: 1292-98.
[56.] Yamaguchi H, Kobayashi K, Osada R, et al. Effects of irradiation of an erbium:YAG laser on root surfaces. J Periodontol1997;68:1151-55.
[57.] Deppe H, Horch HH, Neff A. Conventional versus CO2 laser-assisted treatment of peri-implant defects with the concomitant use of pure-phase beta-tricalcium phosphate: A 5-year clinical report. Int J Oral Maxillofac Implants 2007;22:79-86.
[58.] Stubinger S, Henke J, Donath K, Deppe H. Bone regeneration after peri-implant care with the CO2 laser: A fluorescence microscopy study. Int J Oral Maxillofac Implants 2005;20:203-10.