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Laser in dentistry generally and in prosthodontics particularly: Literature review

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ABSTRACT

Lasers were introduced into the field of clinical dentistry with the hope of overcoming some of the drawbacks posed by the conventional methods of dental procedures. Since its first experiment for dental application in the 1960s, the use of laser has increased rapidly in the last couple of decades. At present, wide varieties of procedures are carried out using lasers. Although soft-tissue laser was initially introduced, but with invention of new-generation laser, it is now widely used on dental hard tissue as well. Commonly used laser in dentistry includes neodymium-yttrium aluminum garnet laser, erbium: yttrium aluminum garnet, CO2, erbium chromium:yttrium scandium gallium garnet, holmium:yttrium aluminum garnet, and diode laser. Introducing lasers into dentistry helped the practitioners to overcome the constraint of conventional procedures. Recently, the foothold of lasers in modern dentistry provided ease, efficiency, specificity, and comfort both to clinicians and patients. This article provides an overview of laser history, lasers wavelength, types and applications of the use of lasers in dentistry. Which the modern practitioner needs to be familiarized with these devices and understand the possibilities and limitations of each device.

1. INTRODUCTION

The word “LASER” denotes “Light Amplification by Stimulated Emission of Radiation,” [1], [2] which generates electromagnetic radiation of uniform wavelength, phase, and polarization that is stimulated by an external field, thereby producing monochromatic, coherent, intense, and collimated light. Understanding the concept of laser wavelength with oral tissue interaction can improve patient management [3], [4].

The principle of the laser was the first known in 1917 when physicist Albert Einstein described the theory of stimulated emission [5]. Lasers in dentistry are considered to be a new technology which is being used in clinical dentistry to overcome some of the drawbacks posed by the conventional dental procedures. This technology was the first used for dental application in the 1960s but its use has increased rapidly in the last

few decades. Today, the lasers technology is used in the compact disc players, as a pointer for lecturer and above all in the medical and dental field. The use of laser technology and its advancements in the field of medicine and dentistry is playing a major role in patient care and well-being [6].

2. HISTORY OF LASERS

Theoretically, laser light production was developed some 90 years ago and first used on extracted tooth about 47 years ago. In 1900, first pulsed Nd: YAG laser was released [6] as to have better interaction with dental hard tissues. By 1970s, researchers found medical carbon dioxide (CO2) and discovered that Nd: YAG lasers can be used in clinical oral soft tissues. Commercially available dental lasers have become more eminent only for the last 3–4 years.

1903	Finsen [7]	Was awarded Nobel Peace Prize and developed carbon arc lamp to treat lupus vulgaris
1917	Albert Einstein [8]	Laid foundation for predecessor “The Maser”
1957	Charles Townes [9-10]	Designed “Maser”
1959	Gordon Gould [11]	Introduced laser to the public
1960	Theodore Maiman [12-14]	First to demonstrate lasers from a ruby crystal; built the first functioning laser with a mixture of helium and neon at Hughes Research Laboratories, Malibu, CA, USA
1964	Patel [11]	Developed CO2 laser at Bell Laboratories
1964	Geusic[6]	Developed Nd: YAG laser
1965	Stern and Sognnaes[6]	Reported ruby laser could vaporize enamel and has thermal effects on dental pulp
1965	Leon Goldman [7], [15], [16]	Used laser on vital tooth and reported biomedical aspects of lasers and its effects on dental caries and other tissues
1966	Lobene et al [15]	Used CO2 lasers in dentistry
1971	Weichman and Johnson [17]	First to use high-powered infrared (IR) CO2 laser in endodontics to seal apical foramen
1974	Yamamoto et al [15], [18- 20]	Used Nd: YAG laser for caries prevention, and for complete debridement of bacteria from apical third of root
1977	Lenz et al [15]	First to use lasers in oral and maxillofacial surgery
1985	Shoji et al [15]	Use of lasers for pulpotomy
1985	Pick et al [15]	First to use lasers in periodontal surgery
1986	Zakirasen et al [15]	Used lasers for sterilization of root canals
1990	FDA [6]	Approved use of laser therapy in intraoral gingival and mucosal tissue surgery
1990	Myers [7]	Introduced the first laser specifically for dentistry

1994	Morita [15]	Introduced Nd: YAG lasers in endodontics
1998	Mazeki et al [15]	Did root canal shaping with Er: YAG laser

Thus, over the last decades, advancements over laser applications led researchers to explore the benefits of laser use in medical and dental fields. Currently, erbium lasers (Er: YAG, Er, Cr: YSGG), Nd: YAG, diode, and CO2 are the most commonly used lasers in dentistry. Clinicians have considered use of erbium lasers as wavelength is said to be safe, effective, and convenient in dentistry when compared with conventional methods.

3. TYPES OF LASERS

- Based as application

1- Soft tissue laser

e.g: Argon, Co2, diode; Nd:YAG.

2- Hard tissue laser

e.g: Er: YAG

3- Resin curing laser

e.g: Argon

- Based on Level of energy emission:

a. soft lasers (low level energy): A thermal low energy lasers emitted at wave length, which are supposed to stimulate cellular activity.

Example: He-Neon; Ga-Arsenide.

b. Hard lasers (High level energy): Thermal lasers emitted at wavelength in the visible infra-red and U.V range.

Example: Er:YAG laser ; Nd: YAG laser. [16]

4. LASER EFFECTS ON TISSUE:

Depending upon the optical properties of the tissue, the light energy from laser may have four different interactions with target tissues

1. Reflection
2. Transmission
3. Scattering
4. Absorption [6], [16].

5. LASER WAVE LENGTHS USED FOR DENTISTRY:

- Argon:

This laser has 2 emission wavelengths, and both are visible to the human eye - 488nm (blue in color) and 514 nm (blue – green). The 488 nm emission is exactly the wavelength needed to activate camphoroquinone, the most commonly used photo initiator that causes polymerization of the resin in light cured composite restorative materials [6], [16].

- CO2 LASER:

o Wavelength – 10,600 nm.

o Well absorbed by water, second only to Er series of lasers

o Rapid soft tissue remover and has a shallow depth of tissue penetration, which is important when treating mucosal lesions.

o Especially useful for cutting dense fibrous tissue.

- Highest absorption in hydroxy apatite; about 1000 times greater than the Er series of lasers [6], [16].

- **Nd:YAG(Neodymium-doped:yttrium aluminum garnret)**
  - Emission wavelength is 1064 nm.
  - Highly absorbed by pigmented tissue and is about 10,000 times more absorbed by water than an argon laser.
  - Common clinical applications are for cutting and coagulation of dental soft tissues with good hemostatic capability
  - Nd: YAG laser energy is absorbed slightly by dental hard tissue; but there is little interaction with sound tooth structure, allowing tissue surgery adjacent to the tooth to be safe and precise. [16]
- **DIODE:**
  - Wave length range from 800-980nm
  - All the diode wavelengths are very well absorbed by pigmented tissue, although hemostasis is not quite as rapid as with the argon laser.
  - Poorly absorbed by tooth structure so that soft tissue surgery can be performed safely in close proximity to enamel, dentine and cementum.
  - An excellent soft tissue surgical laser indicated for cutting and coagulating gingiva and mucosa and for soft tissue curettage, or sulcular debridement [6], [16].
- **THE ERBIUM FAMILY**

The wavelengths that are used are:

- Erbium, Cr:YSGG(Chromium:yttrium-scandium-gallium-garnet) (2780 nm)

Erbium, Cr: YSGG (2780 nm) which has an active medium of a solid crystal of yttrium scandium gallium garnet doped with erbium and chromium.

This laser is widely indicated in restorative and etching procedures. During cavity preparation, the laser provides rough surfaces for bonding without causing any significant cracking in the dental hard tissue. The advantage of this laser for restorative dentistry is that a carious lesion in close proximity to the gingiva can be treated and the soft tissue recontoured with the same instrumentation. Furthermore, tissue retraction for uncovering implants is safe with this wavelength, because there is minimal heat transferred during the procedure. However, the rough surface produced during etching procedures will have a wide range of strengths of enamel bonds which is unreliable. Therefore, the procedure still requires acid etching to obtain equivalent bond strength [18].

- Erbium:YAG(**Erbium-yttrium-aluminum garnet**) (2940 nm)

Erbium: YAG (2940 nm) which has an active medium of a solid crystal of yttrium aluminum garnet doped with erbium. Both lasers aid in caries removal. The laser produces clean, sharp margins during cavity preparation. Since, depth of penetration of laser wavelength is less, so pulpal damage is minimal. During caries removal, since the laser has an anesthetic effect, the analgesia is not routinely indicated in the majority of patients. The laser also assists in removal of endotoxins from root surfaces so providing an anti-microbial effect. These lasers are comfortable to the patients as vibration produces from the laser are less severe in comparison to the conventional high-speed drill. Thus, they are less likely to provoke intraoperative discomfort or pain [17], [18].

- Both have the highest absorption in water of any dental wave length and have a high affinity for hydroxyapatite
- These lasers are ideal for caries removal and tooth preparation when used with a water spray. The health enamel surface can be modified for increased adhesion of restorative materials by exposing it to the laser energy [16].

Table 1: Type and wavelength of laser, used and target tissue

Type of laser	Wavelength(nm) Pulse mode	Chromophores used	Target tissue
Diode	850-1064	Pigments Hemoglobin Melanin	Gingiva, mucosa
Nd:Yag	1064	Pigments Hemoglobin Melanin	Gingiva, mucosa
Er:Yag	2940	Water Hydroxyapatite	Gingiva, mucosa, enamel, dentin, bone
Er, Cr:YSGG	2860	Water Hydroxyapatite	Gingiva, mucosa, enamel, dentin, bone
Co_2	10640	Water	Gingiva, mucosa, enamel, dentin, bone

6. THE USE OF LASERS IN CLINICAL DENTISTRY

Lasers are used in most areas of clinical dentistry and their use is steadily increasing. Their application includes caries detection, caries removal, dental cavity preparation, dentine hypersensitivity management, tooth bleaching, photodynamic therapy, excisional biopsy, aphthous ulcers management, frenectomy, vestibuloplasty, removal of irritation fibroma, removal of hyperplastic tissues, haemangioma, exposure of impacted teeth, gingivectomy and gingivoplasty, apicoectomy, an adjunct to endodontic treatment [6], gingival melanin hyperpigmentation removal [19- 21], non-surgical periodontal treatment of untreated periodontitis [22- 30] and treatment of peri-implant diseases [30- 32]. In terms of endodontic treatment, lasers are used for post-chemomechanical preparation to reduce the remaining bacterial load either by direct irradiation of the canal walls or by laser assisted irrigation via erbium laser group. In terms of gingival melanin hyperpigmentation removal, a recent systematic review identified the use of two laser wavelength groups near infrared diode and erbium group of mid-infrared lasers and failed to draw conclusions on the optimal laser group [21].

In untreated periodontitis patients, lasers have been studied both as monotherapy and as an adjunct to conventional non-surgical periodontal treatment (or non-surgical mechanical instrumentation). In terms of non-surgical periodontal treatment, laser use aims mainly in root surface detoxification. A recent systematic review and meta-analysis showed that in untreated periodontitis patients, laser monotherapy leads to similar clinical improvement to conventional non-surgical periodontal treatment alone [28], which is in agreement with earlier reviews [26], [33]. Systematic reviews on untreated periodontitis failed to show further clinical benefits with the addition of laser treatment to conventional non-surgical periodontal treatment [26], [27], [29]. Specifically, a 2015 systematic review and meta-analysis found that, when used adjunctively to conventional non-surgical periodontal treatment, neither the diode nor the Nd:YAG laser achieves additional clinical benefits beyond that achieved by conventional non-surgical periodontal treatment alone [27]. Then, a recent systematic review showed that the adjunctive use of lasers to conventional non-surgical periodontal treatment does not lead to superior clinical improvement as compared to conventional non-surgical periodontal treatment alone [29]. Nowadays, lasers are used as an adjunct to conventional non-surgical periodontal treatment in periodontitis. It should be stressed that the routine use of any laser for the treatment

of periodontitis cannot be suggested [24]. Decontaminating (or detoxifying) the oral biofilm-contaminated titanium surface without altering it is fundamental for the treatment of periimplantitis [34]. Laser treatment has been proved to be effective in the decontamination of oral biofilm-contaminated titanium surfaces [35], [36]. Several types of lasers have been studied for this purpose. Among them, Er:YAG seems to be the best for titanium surface decontamination without damaging the titanium surface [25], [35], [37]. Specifically, Er:YAG laser and Er, Cr:YSGG laser treatment have been found to be effective methods for the detoxification of oral biofilm-contaminated titanium surfaces without surface alterations [34]. In terms of clinical benefit, a systematic review and meta-analysis showed that laser treatment resulted in similar clinical improvement as compared to conventional implant surface decontamination methods [30]. Another systematic review and meta-analysis showed that the use of lasers is not superior to conventional therapeutic approaches for the treatment of peri-implantitis [31]. An American Academy of Periodontology systematic review showed that lasers as an adjunct to surgical/non-surgical treatment of peri-implant mucositis and peri-implantitis offer minimal clinical benefit [32]. It seems that laser treatment is promising for the management of peri-implantitis, though further research is required to draw safe conclusions.

7. USE OF LASERS IN REMOVABLE PARTIAL DENTURE PROSTHODONTICS:

Laser can be used as an adjunct to removable prosthetic care for many different procedures, including the following:

1. Epulis fissuratum reduction: various researchers have reported the usage of CO2 lasers in treatment of epulis fissatrum with much more satisfactory results than conventional scalpel [38- 41]. There are no contraindications for removal of epulis by the use of lasers known so far.
2. Vestibuloplasty is commonly done pre-prosthetic surgery during the procedure of mouth preparation the use of scalpel delays the continuation of treatment to a vast extent with the help of lasers the healing period has been reduced to a significant interval. Neckel has concluded the results of less post operative pain in patients treated with lasers for vestibuloplasty. Various other researchers have reported same results of less post operative pain and no relapse without any complications [42], [43].
3. Tuberosity reduction: large tuberosities can be a challenge for a prosthodontist in regarding the prosthetic rehabilitation. Literature suggests a clearance of minimum 5mm between the maxillary tuberosity and Mandibular mucosa [44].
4. Torus/exostosis reduction. 8% of the human population affected with equal prevalence in males and females from Mandibular torus. These can be a hindrance for prosthesis and are usually removed before fabrication of prosthesis. Co2 and erbium lasers in combination prove to be efficient for the removal of bony torus [45]. Lasers have been a tool for un eventful heeling of the tissue.
5. Failure of the bond between the acrylic resin and resilient liner material is commonly encountered in clinical practice. Therefore, many studies have been achieved to improve the bond strength of these materials with acrylic resin. Among these studies it was shown that the use of Er:YAG laser surface treatment increased (tensile, shear, peel) bond strength between resilient soft-liner and denture base [46- 48].

Lasers have proved its worth in treating various other soft tissue abnormalities of oral cavity. One amongst those is papillary hyperplasia [44], [49- 53]. Other abnormalities associated with dentures include denture stomatitis, traumatic ulcers angular cheilitis etc.

8. USE OF LASERS IN FIXED PARTIAL DENTURE PROSTHODONTICS:

1.) Gingival troughing: to achieve the best cosmetic results gingival troughing is done. Use of conventional double cord technique is time consuming and can damage the Periodontium of the tooth. Electro surgery also has a disadvantage of delayed wound healing, bone recession etc. lasers allow a clear vision of the gingival margin with minimum bleeding and reduces patient visits and are also highly acceptable to the patients [54].
2.) Laser Sulcular gingivoplasty

3.) Crown Lengthening: among the smile enhancement procedures crown lengthening is an often procedure. It refers to the surgical exposure of longer gingivoincisal length. It can be done by excising either soft tissue or hard tissue or at times both. Erbium lasers provide to be a master tool for bone removal without raising a flap [55], [56].
4.) Pigmented Gingiva is a cosmetic concern amongst the ages diode, Nd:YAG, CO2 and erbium lasers prove to be usage of choice for depigmentation procedures [57- 61].
5.) Bleaching: [62] have summarized lasers among the best for activation of bleaching agents, other than the led lamp and no light source.
6.) Crown and Veneer preparation
7.) Gingival retraction
8.) Removal of gingival overgrowth before re-cementation of bridge
9.) Soft tissue management adjunctive to crown
10.) Defining emergence profile of abutment
11.) Veneer removal
12.) Formation of Pontic sites

9. LASERS IMPLANTOLOGY:
1. Preoperative frenectomy and tissue ablation
2. Preparation of surgical site
3. Decontamination and implant placement
4. Osteotomy
5. Uncovering of implant
6. Treatment of mucositis and periimplantitis Laboratory use:
    1. Laser cutting
    2. Laser welding
    3. Fabrication of prosthesis using CAD-CAM, DLMS, rapid prototyping etc. [16]

10. FACTORS AFFECTING TISSUE ABSORPTION OF LASER LIGHT:
There are several factors affecting tissue absorption of laser light.
a) Laser wavelength
b) Tissue composition
c) Tissue thickness
d) Surface wetness
e) Angle of beam
f) Exposure time
g) Contact mode of laser [63]

11. CONTRAINDICATIONS OF LASER USE AND ITS LIMITATIONS
• Laser should be used with caution in patient having cardiac pacemaker
• It is also not advised to use in cardiac patient with a history of anginal chest pain and arrhythmia
• Use of laser in dental practice requires intensive training and minute precision [64], [65]
• The high cost of laser armamentarium is also a disadvantage in developing country like India
• The cost effectiveness of treatment provided by laser is questionable; moreover, lasers of different wavelength are required for different oral and dental procedure [64], [65]
• It should be used with precaution in patient with immunocompromised state as there is a potential chance of disease transmission through aerosol during the laser procedure. [66]

12. CLINICAL RECOMMENDATION IN PEDIATRIC PRACTICE

• Laser can be used as an alternative to different hard tissue and soft-tissue oral procedure in pediatric patient
• Modifications in clinical procedure and additional use of high-speed handpiece may be needed in pediatric dental practice [66]
• Use of protective eyewear specific for specific laser wavelength is mandatory for dentist, dental team, and also for the patient
• The dental team should have received educational training program in laser before using it in the pediatric population. [66], [67]

13. LASER SAFETY

The use of protective eyewear is mandatory as it causes ocular hazards [68]. The operator must be cautious about accidental exposure to nontarget tissue and the operating area should have a limited accessibility for other persons to minimize its hazardous effects [68]. The presence of flammable materials in laser surgical room should be avoided as it can produce combustion hazards. The use of explosive anesthetic gases is contraindicated when laser surgery is planned under general anesthesia [69]. Moreover, it has to be ensured that the laser is in good working condition and all safeguard are in proper position.

14. CONCLUSION

Advances in the use of laser devices in prosthodontics will continue. Further laboratory and clinical experimentation may determine a significant place for lasers in prosthodontics. To use lasers safely in a clinic, the practitioner should have precise knowledge of the characteristics and effects of each laser system & their applications as well as a full understanding of the conventional as well as surgical treatment procedures and finally should exercise appropriate caution during their use.

15. REFERENCES

[1] Maheshwari S, Jaan A, Vyaasini CS, Yousuf A, Arora G, Chowdhury C. (2020) Laser and its Implications in Dentistry: A Review Article. J Curr Med Res Opin.; 3(8): 579-588.

[2] Colaco AS. (2018) An update on the effect of low level laser therapy on growth factors involved in oral healing. J Dent Lasers; 12(4);6 9.

[3] Sharma AJ, Kumari R, Lahori M. (2019) The evolution of lasers: A delight in dentistry. Guident J; 12:1 6.

[4] Parker S. (2007) Verifiable CPD paper: Introduction, history of lasers and laser light production. Br Dent J; 202:21 31.

[5] Aoki A, Sasaki KM, (2004) Watanabe H, Ishikawa I. Lasers in nonsurgical periodontal therapy. Periodontal 2000; 36:59-97.

[6] David CM, Gupta P. (2015) Lasers in dentistry: A review. Int J Adv Health Sci; 2(8)7 13.

[7] Luke AM, Mathew S, Altawash MM, Madan BM. (2019) Lasers: A review with their applications in oral medicine. J Lasers Med Sci; 10:324 9.

[8] Einstein A. (1917) The Quantum theory of radiation. Physiol Z.; 18:121-8.

[9] Sandhya. (2016) Lasers in dentistry-short review. J Pharm Sci Res.; 8(6):38-41.

[10] Tanushri NM, Naeem A, Taseer B, Ashish C. (2015) Lasers power in dentistry. Int J Multidiscip Res Dev; 2:36 40.

[11] Gross AJ, Hermann TR. (2007) History of lasers. World J Urol; 25:217 37.

[12] Bhatia S, Kohli S. (2013) Lasers in root canal sterilization A review. Int J Sci Study; 1:107 11.

[13] Gupta S, Kumar S. (1960) Lasers in dentistry an overview. Trends Biomater Artif Organs 2011; 25:119 23.

[14] Maiman TH. (1960) Stimulated optical radiation in ruby lasers. Nature; 187: 493-494.

[15] Mensudar R, Anuradha B, Mitthra S, Anupriya VR, Anusha CM, Victoria PS. (2017) Lasers An asset to endodontics. Int J Curr Res; 9(10): 59805 9.

[16] Manjula D, Rajdeep P, Mohammad A, et al: (2017) LASERS IN PROSTHODONTICS, University J Dent Scie;3(2):9-12.

[17] Hossain M, Nakamura Y, Yamada Y, Kimura Y, Matsumoto N, Matsumoto K. (1999) Effects of Er,Cr: YSGG laser irradiation in human enamel and dentin: Ablation and morphological studies. J Clin Laser Med Surg; 17:155-9.

[18] Frentzen M, Hoort HJ. (1992) The effect of Er: YAG irradiation on enamel and dentin. J Dent Res; 71:571.

[19] Ishii, S.; Aoki, A.; Kawashima, Y.; Watanabe, H.; Ishikawa, I. (2002) Application of an Er:YAG laser to remove gingival melanin hyperpigmentation-treatment procedure and clinical evaluation. J. Jpn. Soc. Laser Dent; 13: 89–96.

[20] Nammour, S.; El Mobadder, M.; Namour, M.; Namour, A.; Rompen, E.; Maalouf, E.; Brugnera, A., Jr.; Brugnera, A.P.; Vescovi, P.; Zeinoun, T. (2020) A Randomized Comparative Clinical Study to Evaluate the Longevity of Esthetic Results of Gingival Melanin Depigmentation Treatment Using Different Laser Wavelengths (Diode, CO2, and Er:YAG). Photobiomodul. Photomed. Laser Surg; 38: 167–173.

[21] Muruppel, A.M.; Pai, B.S.J.; Bhat, S.; Parker, S.; Lynch, E. (2020) Laser-Assisted Depigmentation—An Introspection of the Science, Techniques, and Perceptions. Dent. J.;8: 88

[22] Cobb, C.M. (2016) Is there clinical benefit from using a diode or neodymium:yttrium-aluminum-garnet laser in the treatment of periodontitis? J. Periodontol; 87: 1117–1131.

[23] Cobb, C.M. (2017) Lasers and the treatment of periodontitis: The essence and the noise. Periodontology 2000; 75: 205–295.

[24] Cobb, C.M. (2006) Lasers in Periodontics: A Review of the Literature. J. Periodontol, 77, 545–564.

[25] Schwarz, F.; Rothamel, D.; Sculean, A.; Georg, T.; Scherbaum, W.; Beker, J. (2003) Effects of an Er:YAG laser and the vector ultrasonic system on the biocompatibility of titanium implants in cultures of human osteoblast-like cells. Clin. Oral Implants Res; 14: 784–792.

[26] Zhao, Y.; Yin, Y.; Tao, L.; Nie, P.; Tang, Y.; Zhu, M. (2014) Er:YAG laser versus scaling and root planing as alternative or adjuvant for chronic periodontitis treatment: A systematic review. J. Clin. Periodontol.; 41: 1069–1079.

[27] Smiley, C.J.; Tracy, S.L.; Abt, E.; Michalowicz, B.S.; John, M.T.; Gunsolley, J.; Cobb, C.M.; Rossman, J.; Harrel, S.K.; Forrest, J.L.; et al. (2015) Systematic review and meta-analysis on the nonsurgical treatment of chronic periodontitis by means of scaling and root planning with or without adjuncts. J. Am. Dent. Assoc.; 146: 508–524.

[28] Lin, Z.; Franz, J.; Strauss, F.J.; Lang, N.P.; Sculean, A.; Salvi, G.E.; Stähli, A. (2021) Efficacy of laser monotherapy or non-surgical mechanical instrumentation in the management of untreated periodontitis patients. A systematic review and meta-analysis. Clin. Oral Investig.; 25: 375–391.

[29] Salvi, G.E.; Stahli, A.; Schmidt, J.C.; Ramseier, C.A.; Sculean, A.; Walter, C. (2020) Adjunctive laser or antimicrobial photodynamic therapy to non-surgical mechanical instrumentation in patients with untreated periodontitis: A systematic review and meta-analysis. J. Clin. Periodontol.; 47: 176–198.

[30] Mailoa, J.; Lin, G.H.; Chan, H.L.; MacEachern, M.; Wang, H.L. (2014) Clinical outcomes of using lasers for peri-implantitis surface detoxification: A systematic review and meta-analysis. J. Periodontol; 85: 1194–1202.

[31] Kotsakis, G.; Konstantinidis, I.; Karoussis, I.K.; Xiaoye, M.; Haitao, C. (2014) Systematic review and Meta-Analysis of the effect of various laser wavelengths in the treatment of periimplantitis. J. Periodontol.; 85:1203–1213.

[32] Lin, G.H.; Suárez López Del Amo, F.; Wang, H.L. (2018) Laser therapy for treatment of peri-implant mucositis and peri-implantitis: An American Academy of Periodontology best evidence review. J. Periodontol.; 89:766–782.

[33] Schwarz, F.; Aoki, A.; Becker, J.; Sculean, A. (2008) Laser application in non-surgical periodontal therapy: A systematic review. J. Clin. Periodontol.; 35: 29–44.

[34] Alani, A.; Bishop, K. (2014) Peri-implantitis. Part 3: Current modes of management. Br. Dent. J.;217: 345–349.

[35] Park, S.H.; Kim, O.J.; Chung, H.J.; Kim, O.S. (2020) Effect of a Er, Cr:YSGG laser and a Er:YAG laser treatment on oral biofilm contaminated titanium. J. Appl. Oral Sci.;28: e20200528.

[36] Namour, M.; Verspecht, T.; El Mobadder, M.; Teughels, W.; Peremans, A.; Nammour, S.; Rompen, E. Q-Switch. (2020) Nd:YAG Laser-Assisted Elimination of Multi-Species Biofilm on Titanium Surfaces. Materials; 13:1573.

[37] Kreisler, M.; Gotz, H.; Dushner, H.; d'Hoedt, B. (2002) Effects of Nd:YAG, Ho:YAG, Er:YAG, CO2 and GaAIAs laser irradiation on surface properties of endosseous dental implants. Int. J. Oral Maxillofac.

Implants; 17: 202–211

[38] Keng SB, Loh HS: (1992) The treatment of epulis fissuratum of the oral cavity by CO2 laser surgery, J Clin Laser Med Surg;10(4):303-306.

[39] Barak S, Kintz S, Katz J: (1994) The role of lasers in ambulatory oral maxillofacial surgery: operative techniques, Otolaryngol Head Neck Surg;5(4):244-249.

[40] Gaspar L, Szabo G: (2001) Removal of epulis by CO2 laser, J Clin Laser Med Surg;9(4):289-294.

[41] Komori T, Yokoyama K, Takako T, Matsumoto K: (1996) Case reports of epulis treated by CO2 laser without anesthesia, J Clin Laser Med Surg;14(4):189-191.

[42] Neckel CP: (1999) Vestibuloplasty: a retrospective study on conventional and laser operation techniques, Lasers Dent;3593:76-80.

[43] Beer A, Beer F:(2002) Laser preparation technique in vestibuloplasty: a case report, J Oral Laser Appl;2:51-55.

[44] Terry B, Hillenbrand D: (1994) Minor preprosthetic surgical procedures, Dent Clin North Am;38(2):193-216.

[45] Payas G:(2004) Clinical applications of CO2 laser and Er:YAG laser in frenectomy, vestibuloplasty and removal of mandibular bony protuberances, J Acad. Laser Dent;12(2):15-18.

[46] Al-Shakaki H, Al-Essa H: (2020) The effect of Er: YAG laser surface treatment to acrylic resin denture base on the peel bond strength of silicone-based resilient liner, International Journal of Medical and Health Research;6(11):1-4.

[47] Alshakaki H S, Al-Essa H A: (2020) A comparative evaluation of shear bond strength between self-cured resilient liner and denture base resin with different surface treatments, International Journal of Applied Dental Sciences; 6(3): 684-687.

[48] Al-shakaki H, Al-Essa H: (2020) Effect of different surface treatments on tensile bond strength of silicone-based soft denture liner, International Journal of Applied Dental Sciences; 6(3): 259-262.

[49] Regezi J, Sciubba J: (1993) Connective tissue lesions. In Oral pathology: clinical-pathologic correlation, ed 2, Philadelphia, Saunders.

[50] Costello B, Betts N, Barger HD, Fonseca R: (1996) Preprosthetic surgery for the edentulous patient, Dent Clin North Am;40(1):19-38.

[51] Pick R: (1997) The use of laser for treatment of gingival disease, Oral Maxillofac Surg Clin North Am;9(1):1-19.

[52] Pogrel MA: (1989) The carbon dioxide laser in soft tissue preprosthetic surgery, J Prosthet Dent;61:203-208.

[53] Strauss RA: (2000) Lasers in oral and maxillofacial surgery, Dent Clin North Am;44(4):851-873.

[54] Neill ME: (1997) Sulcular debridement and bacterial reduction with the PulseMaster dental laser: clinical evaluation of the effects of pulsed Nd:YAG laser on periodontitis and periodontal pathogens (master's thesis), San Antonio, , University of Texas Graduate School of Biomedical Sciences, pp 123-125.

[55] Lowe RA: (2006) Clinical use of the Er,Cr:YSGG laser for osseous crown lengthening: redefining the standard of care, Pract Proc Aesthet Dent;18(4):S2-S9.

[56] Wan-Yu Tseng, Min-Huey Chen, Hui-Hsin Lu: (2007) Tensile bond strength of Er,Cr:YSGG laser irradiated human dentin to composite inlays with resin cements, Dent Mater J;26(5): 746-755.

[57] Adams T, Pang P: (2004) Lasers in esthetic dentistry, Dent Clin North Am 48:838-860,

[58] Atsawasuwan P, Greethong K, Nimmanov V: (2007) Treatment of gingival hyperpigmentation for esthetic purposes by Nd:YAG laser: report of 4 cases, J Periodontol; 72:315- 321.

[59] Eses E, Haytac MC, et al: (2004) Gingival melanin pigmentation and its treatment with the CO2 laser, Oral Surg Oral Med Oral Pathol Oral Radiol Endod;98:522-527.

[60] Rosa D, Aranha A, DePaola E:(2007) Esthetic treatment of gingival melanin hyperpigmentation with Er:YAG laser: short term clinical observations and patient follow-up, J Periodontol Oct; 78(10):2018-2025.

[61] Tal H, Oegiesser D, Tal M: (2003) Gingival depigmentation by erbium YAG laser: clinical observation and patient responses, J Periodontol;74(11):1660-1667.

[62] Wetter NU, Barrosco MC, Pelino JE: (2004) Dental bleaching efficacy with diode laser and LED irradiation: an in vitro study, Lasers Surg Med; 35(4):254-258.

[63] Uygulamaları PDHL, VARRAK A, KUNT GE and CEYLAN G. (2020) Lasers Applications in Prosthodontics. ES J Dent Sci;1(3):10-14.

[64] Coluzzi DJ. Lasers in dentistry. Commend Contin Educ Dent 2005; 26:429 35.

[65] Olivi G, Genovese MD, Caprioglio C. (2009) Evidence-based dentistry on laser paediatric dentistry: Review and outlook. Eur J Paediatr Dent; 10:29-40.

[66] Galui S, Pal S, Mahata S, Saha S, Sarkar S. (2019) Laser and its use in pediatric dentistry: A review of literature and a recent update. Int J Pedod Rehabil; 4:1 5.

[67] Ando M, van Der Veen MH, Schemehorn BR, Stookey GK. (2001) Comparative study to quantify demineralized enamel in deciduous and permanent teeth using laser and light induced fluorescence techniques. Caries Res; 35:464 70.

[68] Verma SK, Maheshwari S, Singh RK, Chaudhari PK. (2012) Laser in dentistry: An innovative tool in modern dental practice. Natl J Maxillofac Surg; 3:124-32.

[69] Marwah N. (2014) Text Book of Pediatric Dentistry. 3rd ed. India: Jaypee Brothers Medical Publishers (p) Ltd.