

Lasers in Dentistry: In Advancing Front; A Review

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Abstract

LASER is an acronym of Light Amplification by the Stimulated Emission of Radiation. Since 1960s, When Maiman used it for the first time in dentistry, laser have evolved their way in the field, where they are been used for several procedures like caries removal, cavity preparations, dental hypersensitivity treatment, etching, composite polymerization, bleaching, canal sterilization, soft tissue and apical surgeries. With these applications, lasers also presents certain advantages like, minimized bleeding yielding good visibility, decreased swelling and postoperative pain, accelerated healing, controlled collateral damage, reduced need for anesthesia. In recent years, with improved understanding of laser-tissue interactions and advancements in technology, laser have spread their applications from diagnosis to preventive procedures, making them an efficient and valuable tool for dental surgeon in near future.

Keywords: LASER Basics; Laser-Tissue Interactions; Applications in Dentistry; Endodontics; Laser.

Introduction

Since 1960s, with invention of lasers, it had attracted many dental clinician and researchers in recent times. Lasers present with a ton of advantages like reduced patient's anxiety, minimized bleeding yielding good visibility, decreased swelling and postoperative pain, accelerated healing, controlled collateral damage, reduced need for anaesthesia and many more. It has opened new doors towards technology where a small beam can work from detection of incipient caries to surgeries, with all efficiency and precision.

Lasers have allowed easy caries removal, cavity preparations, dental hypersensitivity treatment, etching, composite polymerisation, bleaching, canal sterilisation, soft tissue and apical surgeries,

and many more. With the developing technology and use of thinner, more flexible fibres, the applications of lasers have enhanced in dentistry. This article will highlight about lasers history, tissue interactions, types, and uses of lasers that lay foundation of lasers in dentistry.

History

In 1917, Albert Einstein put forth "The Theory of Stimulated Emission", which formed basis for development of laser.¹ In 1960, Theodore Maiman, a scientist with the Hughes Aircraft Corporation, first developed the working laser device, which emitted a deep red-coloured beam, called as "Ruby Laser", with 0.694 um wavelength. But in 1964, Stern and Sognnaes, reported that it can vaporize



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enamel and have deleterious thermal effects on dental tissues.² Then in 1964, Patel developed CO₂ laser, which had better interactions with dental tissues.³ In 1964, Guesic developed Nd: YAG. Weichman and Johnson, in 1971, first used lasers in endodontics, by utilizing high power infrared CO₂ laser to seal the apical foramen in vitro.⁴ In late 1990s, semiconductors-based diode lasers also emerged. FDA gave clearance to dental hard tissue Er: YAG laser and Er, Cr: YSGG in 1997. Since then, the uses and technology are pacing rapidly.

Mechanism of Action

An action medium is required for production of laser, which can be solid, gas or semiconductor. This active medium when stimulated by electricity or light, produces photons of a specific wavelength. Lasers are characteristically monochromatic, coherent, unidirectional, and emitted from stimulated active medium. In solid state, e.g. Er: YAG lasers, the erbium is stimulated by light from a flash lamp with a process known as optical pumping.⁵ As an erbium atom absorbs a photon, its electrons are excited to a higher energy level. When electron return to a lower energy state, two identical photons are emitted which can further stimulate more atoms in a chain, resulting in amplification of photons. The mirrors as resonators increases this light intensity. Light leaks from the output couplers and these photons form the laser beam.⁶ It is carried to the target tissue by various types of beam and transfer through hardware like mirrors in articulated arms and optical fibres.

Classification of Lasers

A. Based on Light Active Medium

GAS lasers: Argon and CO₂

LIQUID Lasers: Dyes

SOLID lasers: Nd: YAG, Erbium: Yttrium aluminium garnet (Er: YAG), Er: YSGG, Diode

Semiconductors Lasers: Hybrid silicon laser

B. Based on Light Spectrum

- 1) U/V laser 400-800 nm Not used in Dentistry
- 2) Visible Light 400-750 nm Sometimes used in Dentistry
- 3) Infrared Light 750-1000 nm Most Commonly used in Dentistry

Laser-Tissue Interactions

There are 4 types of interactions occurring with target tissue, depending on their optical properties-

Absorption- It is the first and most desired interaction with tissue. The amount of energy absorbed depends on various characteristics of the tissues, such as chromophores, water content, laser wavelength and emission mode.⁷ e.g. Hemoglobin, the molecule that transports oxygen to tissues, reflects red wavelengths, imparting colour to arterial blood, strongly absorbs blue and green wavelength. Melanin, the pigment which imparts colour to skin, strongly absorbs short wavelength lasers. Water. the universally present molecule also

Absorption Curves of Dental Chromophores

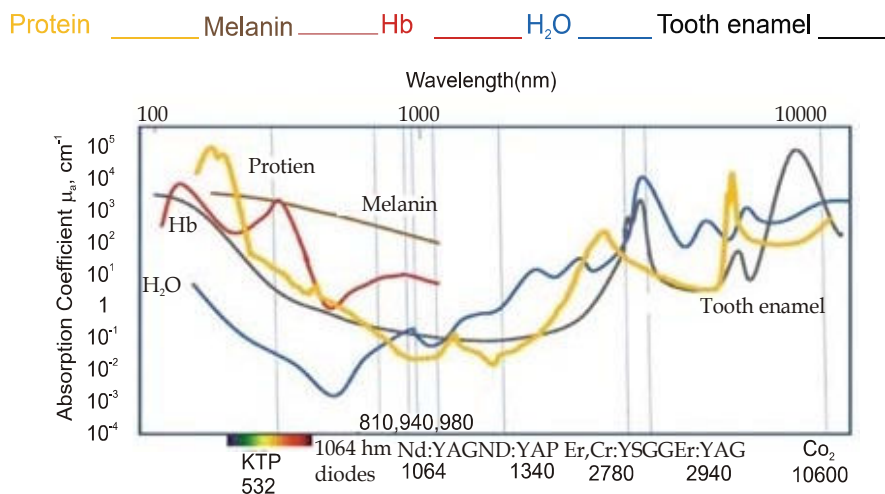


Fig 1. Absorption curves of different dental compounds by various Wavelengths of lasers.

exhibits varying degree of absorption by different wavelengths.

Dental structures contain different amount of water with enamel being the least 4%, then dentine, bone, calculus, caries, and soft tissue (about 70%). Erbium and CO₂ lasers are predominantly absorbed by water.⁸ Another compound most abundantly present in dental hard tissues is hydroxyapatite. Generally, shorter wavelengths (500-1000nm) are readily absorbed in pigmented tissue and blood elements. Argon is attenuated by haemoglobin while diode and Nd: YAG have higher affinity for melanin than haemoglobin. Longer wavelengths are more interactive with water and hydroxyapatite. CO₂ laser is well absorbed in water and greatest affinity for tooth structure.

2. *Transmission*–Energy passes through the tissues without any effect on the target tissues, which is just opposite of absorption. This property is dependent on wavelength of laser. Water, for e.g. is relatively transparent for shorter wavelength of lasers like diode, argon, Nd: YAG, whereas tissue fluids readily absorbs erbium family and CO₂. A classic example to explain the property is diode and Nd: YAG are transmitted through the lens, cornea and iris of the eye and are absorbed on the retina.
3. *Reflection*–It is the property where beam redirects itself off the surface, having no effect on the target tissue. The reflected light could maintain its collimation in a narrow beam or become diffuse. A caries detecting laser device uses this property to measure degree of sound structure. This property can be dangerous as the energy can be redirected to an unintentional target e.g. eyes, which is a major safety concern for lasers.
4. *Scattering*–This property means weakening of intended energy, thereby producing no useful biological effect. Scattering of laser beam could transfer heat to the adjacent tissues of surgical site causing unwanted collateral damage. However, this scattering property may facilitate polymerisation of composites, covering a wider area.

Laser wavelengths used in Dentistry

Several wavelengths are used in dentistry, we would briefly discuss them in this section. These lasers are named according to their active medium, wavelength, delivery system, emission mode, tissue absorption and clinical applications.

Lasers used in dentistry are listed below, according to their wavelengths with shortest being first-

Argon Laser

The laser has argon gas as active medium, which is energized using high-current electrical discharge. It is fiberoptically delivered in continuous wave and gated pulse mode. There are two emission wavelengths used in dentistry: 488 nm, blue in colour and 514 nm, blue green in colour.

The 488 nm emission is the wavelength needed to activate camphorquinone, most commonly used photo initiator used for polymerisation of resin in composite restorations. The divergent beam is used in non-contact mode, to provide curing energy. Some studies showed, increase in strength of the resin cured using argon laser as compared with conventional blue light.⁹ These lasers are also being used in laboratory and chair side for procedures like, light activated bleaching and impression materials.

The 514 nm wavelength is well absorbed in tissues containing hemoglobin, hemosiderin, melanin. Popularized as excellent haemostatic agent and used for treatment of Acute inflammatory periodontal disease and highly vascularised lesions, such as hemangioma.¹⁰

Neither of these wavelengths are absorbed in dental hard tissues or in water. This property of poor absorption into enamel and dentin is advantageous when cutting and sculpting gingival tissues, posing no damage to the tooth structure during the procedure. Both wavelengths can be used in caries detection. When one illuminates the tooth with argon laser, carious areas appear dark orange red and are easily distinguishable from healthy tissues.

Diode

Diode (fig 2) is a solid active medium laser, manufactured from semiconductor crystals, aluminium or indium, gallium and arsenic. The wavelengths available for dental use depends on active medium, 800 nm for aluminium being active medium and 980 nm for indium. Each system delivers energy in continuous wave and gated pulse mode.

All the diode lasers are well absorbed by pigmented tissues and are deep penetrating, controls haemostasis to some extent.

Continuous wave emission of diode laser causes rapid rise in temperature in target tissues. The clinician should use air and water to cool the surgical site. It is an excellent soft tissue laser indicated for cutting and coagulating gingiva and mucosa for sulcular debridement.^{11,12} Another big advantage is the laser is of smaller size and portable.

In addition to surgical lasers, these are used for manufacturing of devices like Diagnodent, which uses visible red diode at 655 nm wavelength and 1mW power. This red energy excites fluorescence from carious tooth structure, which when reflected to detector in the device, analyses and quantifies the degree of caries.¹³



Fig. 2: SIROLaser Blue, FDS, BHU

Neodymium: YAG

Nd: YAG has solid active medium, containing garnet crystal combined with rare earth metals yttrium and aluminium, doped with neodymium ions. The wavelength delivered is of 1064 nm. These instruments in free running pulsed mode, with short pulse durations in microseconds, and features a small flexible tissue contact optic fibres. These lasers are highly absorbed in melanin but less in haemoglobin. Used for cutting and coagulating dental soft tissues and sulcular debridement.^{14,15}

Nd:YAG laser energy is slightly absorbed by dental hard tissue, with little interaction with sound tooth structure, allowing soft tissue surgery without adjacent tooth structure damage. Carious lesions can be easily removed without removing sound tooth structure.

In non-contact mode also, the laser energy penetrates several millimetres, and can be used

for haemostasis, treatment of aphthous ulcers, or pulpal analgesia.

The Erbium Family

There are two different laser wavelengths that uses erbium, that is Erbium, Chromium: YSGG (2790 nm) has an active medium as solid crystal of yttrium scandium gallium garnet that is doped with erbium and chromium.

Er: YAG (2940 nm) (fig 3) has an active medium of solid crystal of yttrium aluminium garnet doped with erbium. Both wavelengths are invisible, mid-infrared and non-ionizing electromagnetic waves.

Both wavelengths are emitted in pulsed mode, where the device contains hollow wave guide or a fibre optic bundle. The fibre diameter is much larger and require air coolant for proper operation. These wavelengths have a high affinity for hydroxyapatite and water.¹⁶⁻¹⁸ The laser gets absorbed into hydroxyl radical of the crystal and into the water bound to the crystalline structures of the tooth. The vaporisation of water in mineral structure causes massive volume explosion, which causes surrounding minerals to explode away.¹⁹

Caries removal and tooth preparation can be done easily using this laser,²⁰ while protecting the sound tooth structure;²¹ increased water content in decayed part allows laser to interact only with diseased tissue.^{22,23}



Fig. 3: Fotona sky walker, IMS, BHU (funded by DST, New Delhi)

CO₂ Laser

The CO₂ laser is a gas active medium laser that contains gaseous constituents of CO₂ molecules pumped via electrical current, producing

wavelength of 10600 nm, delivered through a hollow tube in continuous or gated pulse mode.

This wavelength is well absorbed by water, so can easily cut and coagulate the soft tissue. It has shallow depth penetration thus can be utilised for treating mucosal lesions and can vaporize dense fibrous tissues. This laser can be used in both contact and non-contact modes. After surgery, it may be used in defocused mode to place biological bandage called eschar on wound surface.

This laser has highest absorption in hydroxyapatite, 1000 times greater than erbium. Therefore, tooth adjacent to surgical site must be protected using a metal instrument.

Uses of Lasers in Restorative Dentistry

Hard Tissue Applications

Photochemical Effects –

The argon Laser (488nm) which produces blue light, is extremely effective in curing light-activated composite and similar materials.²⁴ Vargas et al suggested, that argon laser can adequately polymerize composite more rapidly, when compared with conventional visible lights.²⁵

Moreover, Argon laser can also alter the surface chemistry of enamel and dentine, which reduces probability of recurrent caries.²⁶

Argon and Potassium Titanyl Phosphate (KTiOPO₄, KTP) lasers can achieve positive results that are completely unresponsive to conventional photothermal bleaching. This bleaching effect relies on specific absorption of a narrow spectral range of green light (510-540 nm) into the chelate compounds formed between the apatites, porphyrins and tetracycline compounds.²⁷

Cavity preparation, caries and Restorations removal

Er: YAG is being used for removing caries in the enamel and dentine by ablation, without any detrimental temperature changes on the pulp²⁸, same as that with air-rotor devices, except for slight smoothness. The laser can also easily remove cement, composites and glass ionomer. Laser can be used at 1-8 mJ energy (depending on tissue type) and frequency 2-20Hz for cavity preparation, while at 8-13 mJ/cm² for caries prevention.

Etching

Laser (Er, Cr: YSGG) has been evaluated as an alternative to the conventional etching system,

producing micro irregularities and no smear layer.²⁹ But many studies show, adhesion to hard tissues after laser etching to be inferior that obtained by conventional etching.³⁰

Treatment of dentinal Hypersensitivity

Desensitisation of dentinal sensitivity is common treatment, for which most dental patient seeks for. While comparing Er: YAG laser to conventional treatment plans, laser had shown positive results, that to for prolonged duration 31.one can use, Nd or Er: YAG at 30 mJ and 10 Hz with water spray for 2 min.

Diagnostic Aid

Argon and diode laser are popularly used for detection and quantifying of dental caries using diagnodent. Further, diode lasers are used for detection of subgingival calculus, fissure lesions, and testing pulpal blood flow via Laser Doppler Flowmetry. Helium-neon lasers also find their use for scanning phosphor plates of digital radiographs. Nd, Er: YAG are also utilised in spectroscopic analysis and confocal cytometric imaging of soft and hard tissues.

3-D Laser scanner for e-model preparation

The laser scanners can be used as soft tissue scanners, at 250-300 m W/cm² for 10s, creating 3D images of oral and dental structures.^{32,33} With an advantage of reduced cost for impressions making, cast preparation and record keeping.

Endodontics

Pini et al used XeCl excimer laser (308nm) with suitable fibreoptic delivery, at 0.5-1.5 J/cm² gave effective and fast cleaning of canals³⁴. Many studies show, Lasers also provide canal wall glazing, apical plug fusion, microbial control, pulpal tissue debridement, and repair of incomplete vertical root fractures.³⁵

Soft tissue applications

Gingival re-contouring and crown lengthening

Diode laser had emerged as a rescue from painful conventional gingival surgeries, where laser is associated with less pain, discomfort and bleeding. Moreover, healing is rapid and without healing marks.^{36,37}

Wound Healing

At low doses, laser application stimulates proliferation of fibroblasts maturation and locomotion, also contributes to the better tensile

strength of healed wounds. Low-level laser Therapy (LLLT) (e.g. 2J/cm²) is observed to transform fibroblasts into myoblasts as early as 24 hrs 38. LLLT has shown positive results for promoting healing and dentinogenesis, following pulp capping and pulpotomy.³⁹

Post herpetic neuralgia and aphthous ulcer

Many studies have shown that, photo modulation of aphthous ulcers and recurrent herpetic lesions, with LLLT of laser energy (He-Ne) provides pain relief and accelerated healing 40,41. LLLT in case of herpes labialis in prodromal stage (tingling), is believed to accelerate healing and reduce frequency of occurrence of lesion.⁴²

Photoactivated Dye Disinfection using lasers

Low level laser energy is very useful in activating oxygen releasing dyes, causing bacterial killing by damaging their membrane and DNA. This PAD (Photo Activated Dye) Technique is done using low power with diode laser and tononium chloride dye. This helps one to effectively kill bacteria in complex biofilms like subgingival pockets, deep carious lesions and sites of peri-implantitis.^{43,44} PAD technique is effective in killing even resistant bacteria like MRSA, fungi, viruses.⁴⁵

This technique is also crawling its way towards diagnosis and treatment of malignancies. It generates reactive oxygen species, which damages cells and blood vessels, promoting both necrosis and apoptosis of tumour cells.⁴⁶

Removal of inflamed and hypertrophic tissue

Diode lasers can effectively excise and remove the isolated and hypertrophied growths without compromising patient's compliance, with reduced requirement of anaesthesia, haemostatic agent during the procedure.

Frenectomy

High frenum attachment and ankyloglossia, creates several problems in dental health, like diastema, malocclusion and difficulties in deglutition and speech. Laser has permitted excision of Frenum painlessly, with less bleeding, and reduced requirement of surgical packing and postoperative care

Miscellaneous Applications

Laser Analgesia

Many studies have proved analgesic effect of LLLT wavelengths (632-904nm) on nerves by decreasing firing frequency and increasing

threshold of receptors.⁴⁷ Local CO₂ irradiation is believed to reduce orthodontic pain without interfering with the tooth movement.⁴⁸

Nerve repair and Regeneration

LLLT, 4.5 J for 10 days is believed to reduce production of inflammatory mediators, promote neuronal maturation and regeneration after injury.⁴⁹ The direct application of laser has promoted repair and regeneration of inferior alveolar nerve tissue, which was damaged while surgical procedures.

Laser Safety

Despite of being easy to use, lasers bring certain precautions to be taken to ensure safe and effective operation. First and foremost being, wearing protective eyewear, that to of specific wavelength. This protection should be done by anyone in the vicinity of the laser, i.e. operator, patient, assistant and any family member, if near.⁵⁰

Any accidental exposures may be prevented by putting warning signs on the doors, minimizing the reflective surfaces, limiting access to surgical environment, and ensuring good working condition of laser.

The room should be well ventilated for escape of vapours while tissue ablation which may be poisonous to people present in surgical room.

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References

1. Aoki A, Sasaki KM, Watanabe H, Ishikawa I. Lasers in nonsurgical periodontal therapy. *Periodontol* 2000 2004; 36:59-97.
2. Stern RH, Sognaes RF. Laser Effect on Dental Hard Tissues. A Preliminary Report. *J South Calif Dent Assoc* 1965; 33:17-9
3. Karlovic Z, Pezelj-Ribaric S, Miletic I, Jukic S, Grgurevic J, Anic I. Erbium: YAG laser versus ultrasonic in preparation of root-end cavities. *J Endod* 2005; 31:821-3.
4. Yamamoto H, Sato K. Prevention of dental caries by acoustooptically Q-switched Nd: YAG laser irradiation. *J Dent Res* 1980; 59:137
5. Lin S, Liu Q, Peng Q, Lin ML. The ablation threshold of Er: YAG laser and Er, Cr: YSGG laser in dental dentin. *Scientific Research and Essays* 2010;5(16):2128-35
6. Frank F. Laser light and tissue biophysical aspects of medical laser application. *SPIE Lasers Med* 1989; 1353:37-45.

7. Kunjawa J. et al. "Effect of low- intensity (3.75-25J/cm²) near infrared (810nm) laser radiation on red blood cells ATPase activities and membrane structure". *Journal of Clinical Laser Medicine and Surgery* 2004;22(2):111-117
8. Powell GL, Ellis R, Blankenau RJ, Schouten JR. Evaluation of argon laser and conventional light-cured composites. *J Clin Laser Med Surg* 1995; 13:315-7.
9. Finkbeiner RL. The results of 1328 periodontal pockets treated with the argon laser. *J Clin Laser Med Surg* 1995; 13:273-81.
10. Moritz A, Gutknecht N, Doertbudak O. Bacterial reduction in periodontal pockets through irradiation with a diode laser. *J Clin Laser Med Surg* 1997; 15:33-7.
11. Coluzzi DJ. Lasers and soft tissue curettage: an update. *Compendium* 2002; 23:1104-11
12. Tsuda T, Akimoto K, Ohata N, Kobayakawa T, Sakakibara Y, Suga S. Dental health examination of children from nursery schools in Tokyo using the DIAGNO-DENT caries detector. In: Ishikawa I, Frame J, Aoki A, editors. *Lasers in dentistry, revolution of dental treatment in the new millennium*. Amsterdam: Elsevier Science BV; 2003:187-9
13. White JM, Goodis HE, Rose CM. Use of the pulsed Nd: YAG laser for intraoral soft tissue surgery. *Lasers Surg Med* 1991; 11:455-61.
14. Raffetto N, Gutierrez T. Lasers in periodontal therapy, a five-year retrospective. *J CDHA* 2001; 16:17-20
15. Eversole LR, Rizioi IM. Preliminary investigations on the utility of an erbium, chromium YSGG laser. *J Calif Dent Assoc* 1995; 23:41-7.
16. Hossain M, Nakamura Y, Yamada Y, Kimura Y, Matsumoto N, Matsumoto K. Effects of Er, Cr, YSGG laser irradiation in human enamel and dentin. *J Clin Laser Med Surg* 1999; 17:105-9
17. Hibst R, et al. The effect of pulsed Er: YAG laser irradiation on dental tissue. *Laser Med Surg* 1988; 4:163-5.
18. Rechmann P, Goldin D, Henning T. Er: YAG lasers in dentistry: an overview. *SPIE* 1998; 3248:1-13.
19. Aoki A, Ishikawa I, Yamada T, Otsuki M, Watanabe H, Tagami J. A comparison of conventional handpiece versus Erbium: YAG laser for root caries in vitro. *J Rest Dent* 1998; 77:1404-14.
20. [21] Tokonabe H, Kouji R, Watanabe H. Morphological changes of human teeth with Er: YAG irradiation. *J Clin Laser Med Surg* 1999; 17:7-12.
21. DenBesten PK, White JM, Pelino J. The safety and effectiveness of an Er: YAG laser for caries removal and cavity preparation in children. *Med Laser Appl* 2001; 16:215-22.
22. Keller U, Hibst R. Effects of Er: YAG laser in caries treatment: a clinical pilot study. *Lasers Surg Med* 1997; 20:32-8
23. Mercer, c, 1996. *Lasers in dentistry: A review. Part 2: Diagnosis, Treatment and Research*. Dental Update 23: 120-125
24. Vargas, M.A., D.S. Cobb and J.L. Schmit, 1998. Polymerization of composite resins. Argon laser VS conventional light. *Oper. Dent* 23: 87-89
25. Westerman G, Hicks J, Flaitz C, Argon laser curing of fluoride releasing pit and fissure sealant: In vitro caries development. *ASDC J Dent child* 2000;67: 387-389
26. Lin LC, Pitts DL, Burgess LW. An investigation into the feasibility of photobleaching tetracycline-stained teeth. *J Endod* 1988; 14:293-9
27. Armengol V, Jean A, Marion D. Temperature rise during Er: YAG and Nd: YAP laser ablation of dentine. *J Endod* 2000; 26:138-41
28. Hossain M, Nakamura Y, Yamada Y, Kimura Y, Matsumoto N, Matsumoto K. Effects of Er, Cr: YSGG laser irradiation in human enamel and dentin: ablation and morphological studies. *J Clin Laser Med Surg* 1999; 17:155-9
29. Ceballos L, Osorio R, Toledano M, Marshall GW. Microleakage of composite restorations after acid or Er: YAG laser cavity treatment. *Dent Mater* 2001; 17:340-6.
30. Schwarz F, Arweiler N, Georg T, Reich E. Desensitising effects of an Er: YAG laser on hypersensitive dentine, a controlled, prospective clinical study. *J Clin Periodont* 2002; 29:211-5.
31. Schwarz F, Arweiler N, Georg T, Reich E. Desensitising effects of an Er: YAG laser on hypersensitive dentine, a controlled, prospective clinical study. *J Clin Periodont* 2002; 29:211-5.
32. Kau CH, Zhurov AI, Bibb R, Hunter L, Richmond S. The investigation of the changing facial appearance of identical twins employing a three-dimensional imaging system. *Orthod Craniofac Res* 2005; 8:85-90.
33. Pini R, Salinbeni R, Vannini M, Barone R, Clauser C. Laser Dentistry: a new application of excimer laser in root canal therapy. *Lasers Surg Med* 1989; 9: 352-7
34. Zakariasen k, Dederich D, Tulip J. Lasers in dentistry: 'Star Wars' Dreaming or a future reality? *Can Dent Assoc J* 1988;54: 27-30
35. Sarver DM, Yanosky M. Principles of cosmetic dentistry in orthodontics: Part 2. Soft tissue laser technology and cosmetic gingival contouring. *Am J Orthod Dentofac Orthop* 2005; 127:85-90.
36. Sarver DM, Yanosky M. Principles of cosmetic dentistry in orthodontics: Part 3. Laser treatments for tooth eruption and soft tissue problems. *Am J Orthod Dentofac Orthop* 2005; 127:262-4.

37. Pourreau-Schneider N, Ahmed A, Soudry M, Jacquemier J, Kopp F, Franquin JC, et al. Helium-neon laser treatment transforms fibroblasts into myofibroblasts. *Am J Pathol* 1990; 137:171-8.
 38. Kurumada F. A study on the application of Ga-As semiconductor laser to endodontics. The effects of laser irradiation on the activation of inflammatory cells and the vital pulpotomy. *Ohu Daigaku Shigakushi* 1990; 17:233-44.
 39. Ross G, Ross A. Low level lasers in dentistry. *Gen Dent* 2008; 56:629-34.
 40. Posten W, Wrone DA, Dover JS, Arndt KA, Silapunt S, Alam M. Low-level laser therapy for wound healing: Mechanism and efficacy. *Dermatol Surg* 2005; 31:334-40.
 41. Hargate G. A randomized double-blind study comparing the effect of 1072-nm light against placebo for the treatment of herpes labialis. *Clin Exp Dermatol* 2006; 31:638-41.
 42. Walsh LJ. The current status of low-level laser therapy in dentistry. Part 2. Hard tissue applications. *Aust Dent J* 1997; 42:302-6.
 43. Dortbudak O, Haas R, Bernhart T, Mailath-Pokorny G. Lethal photosensitization for decontamination of implant surfaces in the treatment of peri-implantitis. *Clin Oral Implants Res* 2001; 12:104-8.
 44. O'Neill JF, Hope CK, Wilson M. Oral bacteria in multi-species biofilms can be killed by red light in the presence of toluidine blue. *Lasers Surg Med* 2002; 31:86-90.
 45. Dougherty TJ. An update on photodynamic therapy applications. *J Clin Laser Med Surg* 2002; 20:3-7.
 46. Peres F, Felino A, Carvalho JF. Analgesic effect of 904-nm laser radiation (IR) in oral surgery. *Rev Port Estomatol Cir Maxilofac* 1985; 26:205-17.
 47. Turhani D, Scheriau M, Kapral D, Benesch T, Jonke E, Bantleon HP. Pain relief by single low-level laser irradiation in orthodontic patients undergoing fixed appliance therapy. *Am J Orthod Dentofacial Orthop* 2006; 130:371-7.
 48. Mester AF, Snow JB, Shaman P. Photochemical effects of laser irradiation on neuritic outgrowth of olfactory neuroepithelial explants. *Otolaryngol Head Neck Surg* 1991; 105:449-56.
 49. Parker S. Laser regulation and safety in general dental practice. *Br Dent J* 2007;202: 523-32.
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