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An Overview: Laser Applications in Dentistry

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Abstract: Dentistry has entered an exciting era of high technology. Lasers provide new powerful tools that is characterized by a bloodless field and applied in most branches of dentistry. There are many types of lasers, such as Gas laser, Chemical laser, Dye laser, Metal-vapor laser, Solid-state laser and Semiconductor laser. Each laser type has its own unique features, advantages and disadvantages. While one laser may be suitable for some procedures, it will be unsuitable for others, so it is important for the dentist to have a back ground information about this technology and its uses in dentistry.

Key words: Oral surgery, maxillofacial surgery, preventive dentistry, restorative dentistry, endodorties

INTRODUCTION

Since the golden years of the 1960s, Lasers were developed and approved for soft tissue procedures. In 1964 Goldman, Ruben and Sherman reported an issue on laser for spectrographic analysis of the morgain components or supragingival and subgingival calculus. Researchers after that continued to prove the uses of laser in dentistry. There are many different types of lasers used in dentistry and their applications vary. The most common use of lasers is for removing dental caries, old composite fillings, sterilizing infected root canals, bone shaping, aphthous ulcer treatment, crown lengthening, apicoectomy, periodontal treatment and oral surgery. In soft tissue procedures (gigivectomy, frenectomy, curettage, crown lengthening, lesion removal) CO₂ laser, Nd: YAG laser, Ar (Argon) laser, Er: YAG (Erbium doped Yttrium Aluminum Garnet) laser and diode laser are used. While in hard tissue procedures (cutting of enamel) Er:YAG laser is preferable. In composite curing: Argon laser is used (Weesner, 1998).

LASER APPLICATIONS IN ORAL AND MAXILLOFACIAL SURGERY

Lasers are of high value in all types of minor surgery, however, their cost and the difficulty of controlling adverse effects present major limiting factors (Catone and Alling, 1997; Al-Alawi, 2005). In soft tissue cutting, the lasers have a number of advantages over the scalpel or Electro surgery. These advantages are (Catone and Alling, 1997; Carith and Mckenzie, 1985; Nobor, 1989):

- The non-contact technique employed means that the tissue is distorted minimally while cutting
- The incision is self-sterilizing
- The laser is always sharp in cutting
- Postoperative scarring is extremely reduced

So, it should be emphasized first and foremost that lasers are an alternative to conventional surgical methods. CO₂ and diode lasers have become the routine cutting lasers in oral and maxillofacial surgery. Many surgeons used the Nd-YAG laser for homeostasis (Nobor, 1989; Nabi et al., 2010). Many researchers have found that the diode laser can be used to eliminate benign, Premalignant or malignant lesions of the oral soft tissues (Carith and Mckenzie, 1985; Ashour, 2006). However, it does not possess any greater ability than the scalpel to cure these conditions, but rather it is a precise mean of removing the effected tissue with little upset to the patient. The clinical results that many authors got presume a high degree of healing (Catone and Alling, 1997; Carith and Mckenzie, 1985; Nobor, 1989). Many of the inherent properties of
Lasers used for performing soft tissue surgery are advantageous in the surgical management of malignant diseases of the oral cavity and related structures. The ability of the laser to perform haemostatic surgery by sealing blood vessels of a smaller diameter than the laser beam is advantageous because it means that more precise surgery can be carried out in a bloodless field and sealing the vessels may decrease the seeding of malignant cells at the time of surgery (Charstpher et al., 1995). Similarly, the ability of the laser to seal the lymphatics at the time of surgery is advantageous in decreasing the swelling and edema associated with surgery. This may decrease the need for a tracheostomy to be performed in the management of facial edema and may decrease the need for steroids to be administered postoperatively. Sealing of the lymphatics may also decrease the possibility of seeding malignant cells into the lymphatics at the time of surgery. In addition, the ability to seal nerve endings is advantageous in decreasing postoperative discomfort (Fitzpatrick, 1992; Charstpher et al., 1995). The ability of the laser to leave a clean, dry, sealed wound is the probable reason for the noted low infection rate following laser surgery. This is an advantage in the management of malignant disease due to decreasing the need for therapeutic and prophylactic antibiotics (Siseigl et al., 2011; Alanazie et al., 2010a, b). This indicates that laser wounds heal with low levels of discomfort and relatively little scarring and wound contracture suggest that formal reconstruction by means of primary closure, skin grafting, or local flap procedures is not necessary because wounds can be left to heal by secondary intention, giving a good functional result with minimal scarring and lack of movement. Also some procedures previously performed in the hospital can now be performed on an outpatient basis using the laser (Alister and Amy, 1996; Corn, 1981). There are another proven uses for dental soft tissue procedure using lasers: Such as frenectomies, incisional and excisional biopsies, soft-tissue tuberosity reduction, soft-tissue crown lengthening, vestibuloplasty, stage 2 implant recovery, etc. (Carath and Mckenzie, 1985; Jawad, 2008). Oral and maxillofacial surgery are all have the potential use of laser in the treatment, many of the lesions that occur on the surface of the oral mucosa are easily controlled with laser energy (Fitzpatrick, 1992). The use of lasers in conjunction with endoscopes in facial rejuvenation procedures has literally turned cosmetic surgery inside out. Conventional surgical techniques such as brow lifting, blepharoplasty and rhytidectomy have been adapted to incorporate these new technologies: they provide the desired aesthetic results and concomitantly offer the patient less postoperative discomfort and a more rapid recovery (Tina and Tina, 1996; Nicholas et al., 1995; Apfelberg, 1996; Aboud, 2005).

**LASER IN PREVENTIVE DENTISTRY**

Stern and Sognaes (1965) reported that the enamel vaporized when subjected to a ruby laser pulse of about 1 m sec. duration, focused to approximately 1 mm2 when the beam contains between 5 and 20 J mm−2 (500-2000 J cm−2) (Hemachandran and Arumugam, 1983). Gordon (1966) suggested cavity preparations with laser but the replacement of the dental drill with laser is untenable as the laser energy above 1000 J cm−2 at the Dentino Enamel Junction (DEJ) would cause irreversible pulpal changes. Vahl (1968) used electron microscopy and X-ray diffraction to study the effects of laser radiation on enamel. These studies clearly demonstrated ultrastructural and crystallographic changes in response to laser radiation. Featherstone and Neslon (1987) concluded that the potential role of the laser in caries prevention has been presented. Laser enamel showed a lesser effect when subjected to an in vitro procedure which induced a caries-like subsurface demineralization than enamel which was not irradiated. Yamamoto and Ooya (1974) suggested that caries could be prevented using an Nd-YAG laser. This group discovered that laser irradiation slightly altered the enamel surface, reducing subsequent subsurface demineralization. They found a significant difference in solubility between laser irradiated and non-irradiated enamel. Featherstone and Nelson (1987) had conducted studies with enamel and dentin, using pulsed CO2 laser radiation in the 9.32 to 10.49 μm region with energy densities in the 10 to 50 J cm−2 range (Featherstone and Nelson, 1987). This laser treatment caused surface fusion and inhibition of subsequent lesion progression and markedly improved the bonding strength of a composite resin to dentin. Walsh and Perham (1991) reported the potential of the CO2 laser for caries prevention using focused infrared laser radiation on sound enamel and early pit and fissure caries. low-power levels (2-5 W) induced localized melting and resolidification of enamel with little surface destruction. For sound fissures, there is elimination of the fissure space providing a sealant effect. In carious fissures, carious enamel was vaporized and adjacent sound enamel fused to partially eliminate the defect. Argon lasers have been reported to reduce or prevent demineralization of enamel of extracted teeth using energy densities of 25 to 100 J cm−2. At these energy densities no damage would be expected in pulp or in the surrounding enamel. Al-Sayyab (2000) used CO2 laser (λ = 10.6 μm) and fluoride to evaluate their combined effect on the acid dissolution and the inhibition of the progression of in vitro caries-like lesions in dental enamel and root. He used continuous and pulsed modes of laser operation, different number of laser pulses, different power densities and different terms of topical fluoride.
application. The caries inhibitory effects reached up to 60% in enamel specimens and up to 69% in root specimens. Al-Tikriti (2001) used polarized light microscope to study the effects of laser radiation on enamel. He used various CW CO₂ laser parameters. A single exposure to CW CO₂ laser radiation was found to be resulted in reductions of in vitro caries like lesion depths. These reductions were up to 61%. The inhibition activity was related directly to the power density and inversely to the exposure time of the CW CO₂ laser radiation. The optimal parameters were 33 W cm⁻² power density and 0.2 exposure time. The carbon dioxide laser (wavelengths of 9.3 and 10.6 μm) are strongly absorbed by water and therefore likely to have the best effect at the lowest intensity. Also the use of pulsed lasers since this would allow for short high intensity delivery of energy with periods of relaxation in between to ensure safety of the pulp and the surrounding tissue (Featherstone and Fried, 2001). De-Melo et al. (2010) used low-intensity diode laser (λ = 808 nm) on dentin as preventive measure from dental erosion and also monitored temperature changes during the course of irradiation. Their study concluded that using a diode laser with levels set at 60 J cm⁻² may induce inhibitory effects on root dentin demineralization without causing any harmful thermal effects. Esteves-Oliveira et al. (2010) used pulsed CO₂ laser (10.6 μm) emitting pulses of 10 msec to reduce dentine calcium and phosphor losses in an artificial caries mode. There results showed that CO₂ laser irradiation (10.6 μm) with 11 J cm⁻² (540 mJ and 10 Hz) of fluoride treated dentine surfaces decreases the loss of calcium and phosphorus in the demineralization process and does not cause excessive temperature increase inside the pulp chamber.

Laser in periodontology: The CO₂ and the Nd: YAG lasers are the most generally used instruments for surgical procedures performed on oral soft tissues (Cohen and Ammons, 1996). Lasers have several potential applications in periodontology, these applications include laser gingivectomy, laser gingivoplasty, laser curettage, laser sterilization of root surfaces and periodontal pockets, laser scaling, frenectomy, crown lengthening, biopsies, tongue lesions, white lesions, aphtous ulcers, laser root planning, distal wedge and tuberosity reduction (Pick and Powell, 1993; Clayman, 1997). Argon laser is used for soft tissue graft and to treat periodontal pockets (Finkbeiner, 1995) while diode lasers are used in sulcular debridement and in bacterial reduction in periodontal pockets (Barr et al., 1998; Moritz et al., 1997a, b, 1998a). Gursoy-Mert et al. (2010) used Er:YAG laser in the treatment of acute streptococcal gingivitis both clinically and microbiologically. The results showed that Er:YAG laser is a promising and effective as conventional periodontal therapy in the treatment of acute streptococcal gingivitis. De Oliveira et al. (2010) reported that Er, Cr: YSGG laser irradiation on root surfaces for adhesion of blood components produced rougher root surfaces than treatment by scaling and root planing. However, it did not interfere with the adhesion of blood components to the root surfaces.

LASER IN RESTORATIVE DENTISTRY

Laser polymerization: The possibility of using lasers for curing has been considered for sometimes. The argon laser, which produces blue light, exactly the right wavelength 488 nm is extremely effective in curing light-activated composite and similar materials (Mercer, 1996). Blankenau et al. (1991) have shown that polymerization of microfilled resin is significantly greater when using the argon laser than conventional visible light sources. Vargas et al. (1998) suggested comparable polymerization using the argon laser versus a conventional visible light to polymerize light activated composite resins. Resin polymerization was accomplished using the argon laser at reduced exposure times. The argon laser can adequately polymerize composite more rapidly compared to a conventional unit, it is a desirable alternative for polymerizing composite resin restorations.

Cutting/ablation of hard dental tissues: Early in laser history, lasers were used to cut operative cavity preparations. First attempts produced too much heat, melted the enamel and damaged the pulp. In the last few years, newer lasers of different wavelengths (Er:YAG and eximer) have renewed interest in this potential. To cut hard tissue effectively, a wavelength should be used that is strongly absorbed by hard tissue. The suitable lasers are Er:YAG, TEA CO₂ (Transversely Excited Atmospheric CO₂) and the excimer (Excited dimer) lasers respectively and are all currently under investigation as hard tissue cutters (Mercer, 1996).

Mechanism of Er:YAG laser ablation of dental hard tissues: The ability of Er:YAG laser to effectively ablate dental hard tissues is ascribed to its 2,940 μm wavelength which is coincident with the main absorption band of water (~3.0 μm) which is known as resonance frequency (Niemz, 2004; Apel et al., 2002; Walsh, 2003). The absorption of the water in this range is so high that scattering and the absorption of other tissue components can be neglected as a first approximation (Vogel and Venugopal, 2003). So, the incident radiation is highly absorbed by water molecules in the dental hard structures, causing sudden heating and water
evaporation. The resulting high stream pressure leads to the occurrence of successive microexplosions with ejection of tissue particles (Niemz, 2004; Hossain et al., 1999; Aoki et al., 2004). The microexplosions are characteristics of the ablation process and determine the microcrater like appearance of the lasered surfaces (Keller and Hibst, 1993). So that, the ablation of tooth structure is achieved via a thermomechanical ablation, with the majority of incident radiation is consumed in the ablation process, leaving very little residual energy for adverse thermal effects on the pulp and the surrounding soft and/or hard tissues (Chimello-Sousa et al., 2005).

Effect of Er:YAG laser ablation on dentin: In 1989, the Er:YAG laser was first described as being able of removing dental hard tissues without causing thermal undesirable effects, such as cracking or charring to the remaining dental tissues (Schein et al., 2003). The morphological aspect of the irradiated dentin has been reported as presenting an irregular surface with open dentinal tubules and lack of smear layer (Schein et al., 2003; Ceballos et al., 2001). These aspects, considered favorable for dentin bonding, are a consequence of the thermomechanical ablation pattern of Er:YAG laser due mainly to its wavelength (2940 nm), which is highly absorbed by water molecules present in the tooth structure (Van Meerbeek et al., 2002). Keller and Hibst (1989) reported that treatment with Er:YAG laser would create surfaces that appear similar to acid etched surfaces. Other investigations have shown that when bonding composite to tooth structure, the Er:YAG laser alone or combined with acid etching produces a surface with bond strength equal or better than that produced by acid etching alone (Delme et al., 2005). Also, Keller and Hibst (1989) and Visuri et al. (1996) postulated that the lasered dentin surface possessed an advantage because of an apparent enlarged surface area for bonding based on the scaly and flaky surface appearance following Er:YAG irradiation (Dunna et al., 2005). Vargas et al. (1997) have shown on Scanning Electron Microscopy (SEM) study that Lased dentin surfaces present several characteristics that appear to be advantageous for resin composite bonding including dentin sterilization, opening of dentinal tubules, a surface with microrregularities without a smeared layer that promotes micromechanical bonding and no demineralization of peritubular and intertubular dentin. Ceballos et al. (2002) proposed that the ablation of dentin fused collagen fibrils together resulting in a lack of interfibrillar space, restricting resin diffusion into the subsurface intertubular dentin. However, a study was made by the same researchers suggesting that when an acid is applied after Er:YAG laser irradiation on dentin, a microrregular surface and opened tubules are obtained, so hybrid layer and resin tag formation occurs. This situation could positively influence the bonding between dentin and resin (De Souza et al., 2004; Ceballos et al., 2001; Van Meerbeek et al., 2002). This comes into agreement with the findings of Delme et al. (2005) who found less marginal leakage of Class V composite restorations when phosphoric acid conditioning was accomplished in the Er:YAG lasered cavities. This may be due to the fact that Er:YAG laser does not demineralize the dentin surface or widen the tubule entrance with no exposure of the collagen matrix (De Souza et al., 2004; Ceballos et al., 2001). On other hand, since the intertubular dentin contains more water and has a lower mineral content than the peritubular dentin, it is selectively ablated more than the peritubular dentin, leaving protruding dentinal tubules with a cuff like appearance. This may also contribute to an increase in the bonding area (Ceballos et al., 2002). This may be the main difference between acid etching and Er:YAG laser action related to dentin and the effect on the morphology of dentinal tubules. When an acid etchant is applied, the peritubular dentin is preferentially etched, resulting in funnel shaped openings to the tubules and this morphology may contribute with polymerization shrinkage to pull the resin tags away from the walls of the tubules. Er:YAG laser irradiation produces no demineralization of the peritubular dentin and the dentinal tubules remain open with no widening. Visuri et al. (1996) also showed by SEM analysis that the Er:YAG laser created open dentin tubules that allowed for the development of resin tags (Ceballos et al., 2001) (Fig. 1). Also it had been reported the presence of peritubular dentin even after acid etching that might be due to increased acid resistance of the dentin surface by the laser, since it has been reported

![Fig. 1: Scanning electron microscopic picture of a dentin surface after Er:Yag laser preparation (X3000) (Bar = 10 μm)](Delme et al., 2005)
Ablation of dental filling material: The Er:YAG lasers can be used to ablate a range of restorative filling materials (Clarkson, 1992).

Laser in endodontics: The first laser use in endodontics was reported by Weichman and Johnson (1971) who attempted to seal the apical foramen in vitro by means of a high power-infrared (CO₂) laser. Dentine hypersensitivity is characterized by short, sharp pain arising from exposed dentine in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or pathology (Holland et al., 1997). The first laser use for the treatment of dentine hypersensitivity was reported by Matsumoto et al. (1985) using Nd:YAG laser. The lasers used for the treatment of dentine hypersensitivity are divided into two groups: low output power (low level) lasers [He-Ne and GaAlAs (diode) lasers] and middle output power lasers (Nd:YAG and CO₂ lasers) (Kimura et al., 2000b). In general, the efficacy of lasers is higher than other methods, but in severe cases, it is less effective. It is necessary to consider the severity of denital hypersensitivity before laser use (Abdul Qader, 2006).

Pulp capping and pulpotomy: If a laser is used for these procedures, a bloodless field would be easier to achieve because laser has the ability to vaporize tissue, coagulate and seal small blood vessels. Moreover, the treated wound surface would be sterilized (Kimura et al., 2000b). Moritz et al. (1998a,b) reported that the CO₂ laser was a valuable aid in direct pulp capping in human patients. The first laser pulpotomy was performed using the CO₂ laser in dogs (Shoji et al., 1985), similar work using the Nd:YAG laser was performed in dogs and rats. The Ga-As semiconductor laser was used for this purpose in mice and the Ar laser in swines (Kimura et al., 2000b). No detectable damage was observed in the radicular portions of irradiated pulps with the CO₂ laser (Shoji et al., 1985). Wound healing of the irradiated pulp seemed to be better than that of controls at 1 week and dentine bridge formation in the irradiated pulp was stimulated at 4 and 12 weeks after operation using the Nd:YAG laser (Ebihara, 1989). Direct effects on the pulp were examined using Nd:YAG laser and CO₂ laser. In both cases, no underlying tissue damage was found in using ablated laser, with the presence of secondary dentine and a regular odontoblast layer. For pulp capping and pulpotomy, an appropriate parameter must be selected, because of unsuccessful treatment by the too strong laser energy (Kimura et al., 2000a).

Modification of root canal walls: Endodontic instrumentation produces organic and mineral debris on the wall of the root canal. Although this smear layer may be beneficial, that provides an obstruction of tubules and decrease dentine permeability, it also may harbour bacteria and bacterial products (Fogel and Pashley, 1990). For these reasons, the removal of the smear layer by laser and its replacement with an uncontaminated chemical sealant, or sealing by melting the dentine surface, has become a goal. The CO₂ laser, emitting in the 9.3-10.6 μm
region caused surface fusion and inhibition of subsequent lesion progression in dentine and improved the bonding strength of a composite resin to dentine. Using the Nd:YAG laser stimulate the application of a thin fiber in root canals (Kimura et al., 2000b). Argon laser irradiation can achieve an efficient cleaning effect on instrumented root canal surfaces and laser irradiation can be enhanced by the presence of Ag (NH3)2F solution (Harashina et al., 1998). Er:YAG laser irradiation was more effective in removing the smear layer and debris on root canal walls than the Ar or Nd:YAG laser, therefore the removal of smear layer and debris by lasers is possible. However, it is hard to clean all root canal walls because the laser is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls (Kimura et al., 2000b).

**Sterilization of root canals:** Numerous studies in sterilization of root canals have been performed using CO2 and Nd:YAG lasers (Goff et al., 1999; Khosravi et al., 2008). The Nd:YAG laser is more popular, because a thin fibre-optic delivery system for entering narrow root canals is available with this device (Kimura et al., 2000b). It was observed that the argon laser using the 100 μm fiber, was more effective than the 200 μm fiber for obtaining a sterilized root canal under the test conditions. Oitknecht et al. (2000) concluded that the diode laser radiation (810 nm) reduces the number of bacteria in deep layers of infected root canal wall dentin. Mehler et al. (1999) stated that Er:YAG-laser radiation exerts very effective antimicrobial properties in dental root canals. This sterilizing effect of the laser results from the generated heat, which should not however, damage the healthy tissue adjacent to the irradiated area. Recently Nd:YAG laser was proved to be useful to remove debris and smear layer causes melting of the internal structure in instrumented root canal wall (Al-Qalamy, 2001).

**Effect on periodontal tissues:** The tooth root is in contact with the alveolar bone via the periodontal membrane and ligament. During laser usage for intracanal applications, thermal injury to periodontal tissues is of concern. It was found that the threshold level for bone survival was 47°C for 1 min (Kimura et al., 2000b). It was observed that the temperature elevation on the root. Surface during Nd:YAG laser irradiation in the root canal did not exceed 10°C only when the laser energy output was below 100 mJ pulse and under 20 pulses sec−1 (Lan, 1999), so that to minimize the rise in tissue temperature within the target and around areas, use of the Q-switched nanosecond pulsed mode is beneficial (Kimura et al., 2000b).

**Table 1: Laser applications in dentistry**

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Wavelength (nm)</th>
<th>Mode of operation (W)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>488, 514</td>
<td>CW</td>
<td>1-20</td>
</tr>
<tr>
<td>Diode</td>
<td>650, 980</td>
<td>CW pulsed</td>
<td>1-10</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1064</td>
<td>CW Pulsed</td>
<td>50-100</td>
</tr>
<tr>
<td>Ho:YAG</td>
<td>2100</td>
<td>Pulsed</td>
<td>25</td>
</tr>
<tr>
<td>Er:YAG</td>
<td>2940</td>
<td>Pulsed</td>
<td>3</td>
</tr>
<tr>
<td>CO2</td>
<td>9600, 10650</td>
<td>CW</td>
<td>10-100</td>
</tr>
</tbody>
</table>

**Lasers in orthodontics:** Lasers are used to etch enamel and to cure resins. They are used in the two steps involved in the attachment of orthodontic brackets to teeth. Although, generally, the strength of laser-etched bonds is not better than that obtained with acid, great precision in the demarcation of the etch site should be possible (Walsh and Perham, 1991). Also Low Level Laser Therapy (LLLT) is now being used for Biostimulation in orthodontics in order to improve bone and soft tissue remodeling during orthodontic treatment with reducing the time of treatment. Altan et al. (2010) used 820 nm diode laser on osteoclastic and osteoblastic cell proliferation-activity during orthodontic tooth movement. Their findings showed that low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement.

**Laser types used in dental treatments:** The laser applications in dentistry are wide and dependant on the laser type used. They are listed in the Table 1 (Jarjees, 2005).

**CONCLUSION**

In this study, Laser applications in dentistry are reviewed. The laser types were categorized based on it dentistry application. This academic review shows that the usage of lasers in dentistry is beneficial and promising. It is widely used in different dental fields and
treatments that give good results compared with traditional treatments. However, it still needs time to be better accepted by dentists and require farther studies to explore more of its advantages.

REFERENCES


